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Abstract

A widely applicable computational model of buoyant moist plumes in turbulent atmospheres has been constructed. To achieve this a one dimensional Planetary Boundary Layer (P.B.L.) model has been developed to account for atmospheric turbulence while the two dimensional time dependent fluid mechanics equations which govern plume behavior are numerically integrated. A cloud microphysics model has been incorporated into the basic numerical code to account properly for the water content of the plume. The overall dynamics of the plume is quite general. The buoyancy source in the plume include both the sensible heat and the latent heat absorbed or released in the plume. The turbulence of the plume accounts for buoyancy generated or destroyed turbulence and a universal k-ε model has been set up along with the k-σ model.

The model is validated against complex field cases to demonstrate its ability to reproduce solutions to problems that are known. Comparisons to visible plume data show that both the dynamics of the plume are calculated with an acceptable accuracy. Comparisons with "conventional" entrainment model show that the model can simulate plumes better since it takes into account more physical phenomena.

TABLE OF CONTENTS

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1 PROBLEM DESCRIPTION AND SOLUTION

1.1 Introduction

With the recent concern in the nuclear industry about emergency planning, and with the renewed global interest in pollution effects from burning of coal and synthetic fuels, the need has become incresingly great for a quantitative model that predicts the detailed downwind distribution of pollutants from smokestacks, cooling towers, and nuclear plants. However, the complexity of the physical phenomena involved in the modelling of plumes makes it very difficult [1] to build a genuinely three-dimensional model without making the cost of the analysis prohibitively great. Consequently, in order to reduce the cost of computation and for the sake of wider applications and the repetition of analysis, two-dimensional models have been suggested by a number of scientists [2]. However, these models suffer from the lack of adequate treatment of plume-generated turbulence, and/or fail to describe atmospheric turbulence. Small laboratory experiments cannot simulate the important turbulent and thermal characteristics of the atmosphere, and since plumes may be impractical to produce, plume modelling has needed a more systematic approach.

A three-dimensional plume model developed at M.I.T. [3] has been extended to account properly for moisture and atmospheric turbulence, in order to simulate atmospheric dominated moist plumes.

The purpose of this work is to construct a widely applicable model of moist plume behavior in realistic atmospheres. To do this a second order closure model is constructed in order to predict the turbulent fluctuations of the atmosphere to the plume model. A moisture model is implemented to account properly for the water content and its thermodynamic state.

1.2 Background and Problem Description

1.2.1. Historical Background

The dispersion of pollutants emitted from chimnies, smokestacks, cooling towers has undoubtedly been a problem of practical interest since the beginning of the industrial revolution. Relatively recent concern about the harmful levels of air pollution in the major urban areas of industrialized nations and the institution of public programs to ensure the abatement of air pollutant emissions has rekindled an interest in the long-standing problem of how to dispose of the gaseous waste products into the atmosphere without causing environmental or public health damage.

The early scientific studies of diffusion of passive pollutants in the atmosphere recognized the role of atmospheric turbulence in dispersing effluent from a point source. Taylor's [4] first example illustration of his theory of diffusion by continuous movements was that of smoke from a chimney. In the subsequent years under the growing impetus of air pollution problems of increasing severity, various empirical extensions of Taylor's work were devised, the most notable of which was due to Sutton [5]. Simultaneously, growing interest in and understanding of turbulence properties of the atmospheric boundary layer have lead to improvements in the ability to predict the dispersion of air pollutants from solitary stationary sources. In recent decades, the emission of sulfur dioxide from fossil-fueled power plants and radioactive gaseous byproducts from nuclear-fission power plants have been prominent examples of the application of this understanding to air quality control.

1.2.3 Characteristics of Moist Bent-Over Buoyant Plumes

The emission from a natural-draft cooling tower into an ambient environment resembles the classic problem of a jet in a free environment. More precisely it is a problem of a vertical jet of finite size with initial momentum and buoyancy being dispersed in a crosswind. It is reminiscent of the emission of stack gases into the atmosphere from a fossil-fired plant. Unlike the stack, however, the cooling tower has a much larger exit diameter, a much smaller temperature difference with the ambient environment (less buoyancy) and a smaller exit velocity (less momentum per unit mass). The smaller exit velocity at the outlet for the cooling tower sometimes permits downwash plume flows under conditions of moderate and high winds. In such a case, the wake generated behind the cooling tower due to the crosswind interaction with the tower will provide a low pressure field below the plume which has the effect of pulling the plume downward and increasing the rate of entrainment of the plume. The effect of the tower structure thus complicates the free-jet problem. A second complication to the free jet problem is the presence of moisture in the plume. Due to thermodynamic processes present inside the tower, the plume is generally saturated with moisture at the exit and contains some liquid recondensate. Additional liquid water can be formed via condensation when the warm moist plume mixes with the cooler ambient air, and when the plume cools during adiabatic ascent. This condensation releases latent heat, warming the plume further. Later in the plume history, the plume moisture tends to disperse below the saturation level due to ambient mixing but because of evaporation of accumulated liquid water the saturation state of the plume is maintained. A common assumption in modelling is that the plume is visible whenever liquid water is present in the plume. It should be noted that the treatment of condensation/evaporation energetics in the plume provides feedback to the plume temperature, increasing it during condensation and decreasing it during the evaporation phase. Generally, however, moisture thermodynamics significantly affect the dynamics of the plume only under extreme conditions such as very cold and/or very humid ambient atmospheres.

1.2.3 Overview of Plume Models

Atmospheric plume behavior can be separated into three successive stages:

1) The rising, convectively mixing phase in which the initially round plume becomes bent over by crosswinds, and in which mixing with the ambient atmosphere is the result primarily of buoyant convection in which a symmetrical line vortex pair is established within the plume, and flows across the plume boundaries are outward at the top, inward at the bottom, and approximately nil at the sides;

2) A non-buoyant intermediate phase in which the plume is in dynamic equilibrium with its surroundings, but in which the previously established internal circulation persists; and

3) A terminal stage in which internal circulation has ceased, and where plume spreading occurrs via turbulent diffusion due to turbulence of the ambient atmosphere.

Considered in this paragraph are three types of models: the Pasquill-type models or correlations, the integral entrainment models, and the numerical models.

In the Pasquill-type models the pollutant concentrations in the plume cross-section are assumed to fit Gaussian distributions of height and width of plume material. In essence, the model parameters (standard deviations of the Gaussian distributions) are simply ad-hoc replicae of a set of experimental results; as such, the models are unable to predict results in cases for which experiments have not been performed. The wealth of non-passive effluents and the rich variations in the meteorological state of the atmosphere serve to guarantee that cases outside the Pasquill-type models will always exist.

The entrainment models develop a much less idealized and much more physically-based picture of the fluid motions in the plume. Typically these models are successful in analyzing the initial plume behavior, where the self-generated plume turbulence dominates atmospheric turbulence. Entrainment models are not able to account for atmosphere-plume interactions in the latter two-plume evolution stages. Consequently, the entrainment models are generally able to analyze plumes only in fairly simple atmospheres when analytical solutions are sought. The limitations of the entrainment models are the condition that the plume self-generated turbulence is dominant over the atmosphere turbulence (i.e., they are useful mainly in the initial buoyant rise stage of plume life. This condition eventually breaks down for all plumes commonly at downwind distances for which the solution is still needed) and the basic entrainment velocity assumption, which cannot be obtained from fundamental constants and scale in a straightfoward way.

Numerical plume models are capable of developing the most detailed picture of the fluid motions in the plume. In general the model integrates a closed set of Reynolds averaged fluid mechanics equations either in two or three dimensions. Turbulence leads to a fundamental closure problem in writing this set of equations, so that each model will have a collection of closure assumptions which together form a turbulence model. Numerical models are becoming capable of analyzing the most detailed cases, yet they are often limited by large computing costs. Aside from the computer costs, the tasks of initializing and validating the problem with fully three or two-dimensional data can also quickly become intractable. Until computer costs are reduced greatly, the most useful numerical plume models will likely have to involve two-dimensional simulation used to construct three-dimensional behavior as with the model of this work. The greatest benefit that comes from such models is the wider range of application of the models, and the ease of extending them to new cases.

1.2.4 Scope of the Work

In Bennett's work the VARR II computer code was reinterpreted in order to model buoyant plumes in the atmosphere. However, the model was limited to simulations of dry plume dynamics. The atmospheric turbulence parameter (turbulent kinetic energy, turbulent kinematic viscosity) were prescribed by either measured values for a neutral atmosphere or simply guessed at. Finally, the (k-σ) turbulence model did not account for buoyancy generated turbulence.

In this work the following important modeling developments have been accomplished:

- A Planetary Boundary Layer model which yields the magnitude of the atmospheric turbulent fluctuations has been constructed.

The Atmospheric turbulence model supplies the required input profiles for the turbulent kinetic energy and the turbulent kinematic viscosity for use by the Atmospheric plume model.

- A buoyancy correction has been implemented in the plume turbulence model to account for buoyancy generated or suppressed turbulence.

- A moisture model which prescribes the thermodynamic state of the plume has been developed in order to extend the simulations to visible plumes.

- The overall model (Planetary Boundary Layer model plus plume model) has been validated against complex field-experiments [2].

This work constructs a one-dimensional turbulent planetary boundary layer model using the method of invariant modelling developed by Donaldson [6]. The method takes advantage of the invariance properties of the Reynolds stresses in order to develop a collection of closure assumptions. Given the temperature and the velocity profiles the model equations are integrated to yield the steady state Reynolds stresses and the temperature correlations required to be supplied to the plume model.

The turbulence transport model which uses the second-order closure model of Stuhmiller [7] has been reformulated to account for buoyancy generated (or suppressed) turbulence.

The Equilibrium Cloud Microphysics Model developed allows a change of phase to take place in order to restore the plume parcel to an equilibrium state, simultaneously taking into account the change in internal energy due to the phase transition. Inherent to the two-dimensional fluid dynamic simulation formulation of the plume model the program is unable to be initialized adequately for plumes which are released in warm atmospheres. To address this deficiency an integral entrainment model developed by Winiarsky and Frick has been implemented in the code in order to carry, whenever necessary, the plume to a point where it is dilute enough to allow a proper initialization.

The turbulence model is validated against Field measurement data obtained during the Kansas 1968 Field Program for the U.S. Air Force Cambridge Research Laboratories. The visible plume model is validated against a complicated case of atmospheric stability and thermodynamic state and the behavior of the simulation agrees reasonably well with the observed visible plume.

2 LITERATURE REVIEW

The literature review in this work undertakes a broad survey of plume modelling and Planetary Boundary layer (P.B.L.) modelling. In the first section, existing numerical planetary Boundary Layer models are discussed, along with the experimental data base which is available for their validation. In the second part of this review the most recent Numerical Plume models are described. Then, the data base available for the validation of these detailed plume models is discussed.

2.1 Numerical Plume Models

A large number of plume models have been developed that are available as computer programs. However, it is important to make a distinction regarding them. A majority of the models employ the Gaussian plume assumption; as such, the computer is simply being used to look up and present the standard handbook calculations, with minor modifications in some cases. These are not "Numerical Plume models" in the sense that the basic conservation equations are not being integrated to predict the plume development, although computers are being used. Such models are not considered further here. The remaining models in the reviews are truly numerical plume models, and they will be considered next, along with several models that have been reported elsewhere.

2.1.1 Three-Dimensional Plume Models

The most sophisticated numerical plume models have not yet attempted a second-order turbulence closure to the fully three-dimensional flow for non-passive pollutants. The base of all three-dimensional models are the differential equations expressing conservation of mass, energy and momentum. If the Reynolds decomposition is employed, equations for mean quantities can be derived by ensemble-averaging the differential equations to obtain instantaneous quantities. The ensemble-averaged quantities include the Reynolds stresses and scalar fluxes of enthalpy and humidity, for which turbulence models are required. Egler and Ernest [7] have developed such a model, in which a second-order closure is employed. The variance values of enthalpy and humidity are calculated within the second-order closure. However, the model fails to account for atmospheric turbulence. Donaldson's modelling undertakes a second order-closure turbulence for a three-dimensional planetary boundary layer model with a passive pollutant. Because the pollutant is passive it does not affect the flow field or its turbulence, the turbulence is independent of the behavior of the buoyant plume. This is in contrast to the method in this work, where the second-order closure is "tuned" to the development of turbulent buoyant plumes, and is largely independent of PBL turbulence development. Benque, Caudron and Viollet [8] have developed a three-dimensional model. PANACH, a steady-state model solves the three-dimensional equations of continuity, momentum, temperature and passive tracer concentration. The equations are simplified by neglecting all diffusion terms in the windward direction as well as the gradient of pressure in the same direction. As a consequence, a marching solution in the windward direction can be made starting from the tower exit plane $(x = 0)$. These simplifications prevent the PANACH model from handling recirculative motions in the x-direction. The model uses constant eddy viscosity and eddy diffusivities which do not vary in space and time. As in the plume model PANACH transports water downwind and at each step the knowledge of the temperature, the water content and with the use of the Claudius-Clapeyron equation, the model determines whether the plume is visible there or not. Patankar's model of a deflected turbulent jet in three-dimensions also uses a second-order closure model, but does not allow for stratification and buoyancy, although it does allow for non-isotropic turbulent transport in the vertical and horizontal directions.

2.1.2 Two-Dimensional Models

Nester [14] has developed a quasi-three-dimensional by making the bent-over plume assumption thereby eliminating the need for the horizontal momentum equation. In each step plume variables in the crosswind plane are computed. The model solves the vorticity stream function transport equation, the enthalpy transport equation, the water and cloud water transport equation and the rain water transport equation. The turbulence is treated by means of a k-ε model of Spalding. Like PANACH this model fails to treat the initial plum bending correctly because of the bent-over plume assumption. It cannot therefore treat tower downwash effect from a fundamental point of view. Henninger's model [15] solves for continuity, momentum, energy, and moisture with a less-sophisticated zero-equation turbulence closure, and a sophisticated treatment of moisture. The model chooses the downwind alignment (Fig. 3.3.b) which is felt to be a less satisfactory choice than that of the present work.

Similarly Taft's [16] model was a sophisticated moisture model. The mesh is aligned in the crosswind direction. Taft's model is much closer to this work. The principal differences are that Taft uses a one-equation turbulence and does not attempt to prescribe ambient turbulence.

2.2 Numerical Planetary Boundary Layer Models

2.2.1 Three-Dimensional Models

Yamada [17] has developed a three-dimensional time-dependent planetary boundary layer model, which can be used under quite general flow conditions; the results of this model are intended to be used as inputs to air pollution models. The model solves the complete set of primitive equations and combined with a statistical cloud model, it has simulated interaction between water phase changes and basic dynamic variables. Computations are relatively expensive; about 25 minutes of CPU time on an IBM 370/195 are required to simulate a complete diurnal cycle.

Deardorff's [18-19] model is also a three-dimensional model that could be adapted to local air pollution studies, although the expense is likely to be prohibitively great. The model solves the complete set of primitive equations (with an eighteen equation turbulence model). The model currently requires 15 sec of CPU on a CDC-7600 to simulate one second in the atmosphere. Also the specification of boundary conditions on a three-dimensional mesh would require a very elaborate reporting network.

2.2.2 Two-Dimensional Models

Early attempts to simulate the planetary boundary layer numerically are those by Estoque [20], Estoque and Bumralkhar [21], Lavoie [22], etc. These models can be classified as hydrostatic and incompres incompressible approximations of atmosphere flow. The mesh is aligned in the downwind configuration 3.3.b. Topography as well as radiative transfer are not included in the models. Lavoie's model is a three-layer depth averaged mesoscale model of the planetary boundary layer whereas Estoque uses a fine resolution vertical grid. Turbulence closure of the momentum and energy equations was achieved using K-type models with constant diffusion coefficients. Two-dimensional non-hydrostatic models were written to simulate convection problems in the atmosphere. They include mathematical models and parameterizations of cloud microphysics and precipitation formation. Takeda's [23] and Orville's [24] work are examples of this modeling approach. Takeda's model has been adapted and further developed to simulate cooling tower plumes by Henninger.

2.2.3 One Dimensional Models

One dimensional numerical models of the PBL have been prevalent for some time, however, their basic weakness is the assumption of a gradient flux relationship. The magnitude of the eddy coefficient and its dependence upon thermal stability are generally not known above the surface layer. Stevens [25] considered nocturnal temperature variations due to diffusion in both soil and atmospheric boundary layers. A diffusion equation with time and height as independent variables was integrated for a prescribed initial vertical temperature profile and specified diffusion coefficients. Estoque [26] investigated the response of the wind and temperature fields to a temperature value imposed at the ground assuming that horizontal advection is negligible. The weakness of the k-type one dimensional models are overcome in the second moment approach developed by Donaldson [27].

Although a height dependent mixing length must be supplied to the model, its ability to reproduce observed data is good. (This approach is adopted in this work.) A description of the method is presented in Chapter 4 of this work.

3 HYDRODYNAMIC MODEL

3.1 Introduction

It is not the purpose of this chapter to undertake the detailed discussion of the hydrodynamic equations used in the model. However, since we will refer to them frequently in this work, and for the sake of completeness, a brief description is presented below. For a more detailed analysis of the equations integrated by VARR-II see Appendix A or the previous work of Bennett [3]. This discussion reiterates the important assumptions contained in the Buoyant plume model which were developed outside this work.

3.2 The Equations of Motion

The set of equations governing the flow of gases and liquids consists of three equations for conservation of momentum (the Navier-Stokes equations), an equation for conservation of mass (the continuity equation), a thermodynamic energy equation (the internal energy equation) and an equation of state. This system of six equations describes the dependence of three velocity components, pressure, temperature and density upon the spatial coordinates and upon time.

The fluid perturbations are generally assumed to be incompressible in the Boussinesq sense. This assumption alleviates some of the mathematical difficulties associated with the treatment of the full set of equations.

The main assumptions associated with Boussinesq type fluids are the following.

- the ratio $|\rho'/\rho_0| << 1$, where $\rho' = \rho - \rho_0$ and ρ_0 is the density of the reference state of the fluid,
- the ratio $|T'/T_0| << 1$, where $T' = T - T_0$ and T_0 is the temperature of the reference state, often chosen so that

  $$\frac{dT_0}{dx_3} = -\frac{g}{c_\rho} = -\gamma_d$$

  γ_d being the dry adiabatic lapse rate.
- The kinematic viscosity $\mu = \rho\nu$ is constant throughout the fluid.
- The molecular heat conductivity k_T is constant throughout the fluid.
- The ratio $|P/p_0| << 1$, where P_0 is the static pressure of the reference state which obeys the hydrostatic condition

  $$\frac{dP_0}{dx_3} = -g\rho_0$$

  and $\eta = P - P_0$.
- The heat generated by viscous stresses may be neglected in the thermodynamic energy equation.

- The vertical scales of the motion are small compared to the scale height

$$\left|\frac{1}{u_j}\frac{\partial u_j}{\partial x_j}\right|^{-1} << \left|\frac{1}{\rho_0}\frac{\partial \rho_0}{\partial x_j}\right|^{-1}$$

With these approximations, the equations for the perturbations can be written as:

Continuity Equation:

$$\frac{\partial u_j}{\partial x_j} = 0 \tag{3.4}$$

Momentum Equation:

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = - \frac{1}{\rho_0}\frac{\partial p}{\partial x_i} - \frac{\rho}{\rho_0} g_i \delta_{i3} + \frac{\mu_0}{\rho_0}\frac{\partial^2 u_i}{\partial x_j^2} - 2\Omega\varepsilon_{ijk}\eta_j u_k \tag{3.5}$$

where the η_j are the components of a unit vector parallel to the earth's axis of rotation, and Ω the angular frequency of rotation.

The Energy Equation:

$$\frac{\partial T}{\partial t} + u_j \frac{\partial T}{\partial x_j} = P_r^{-1} \frac{\mu_0}{\rho_0}\frac{\partial^2 T}{\partial x_j^2} \tag{3.6}$$

where P_r is the Prandtl number $P_r = \dfrac{\mu}{c_p k_T}$

Equation of State:

$$\frac{\rho'}{\rho_0} = - \frac{T'}{T_0} \tag{3.7}$$

3.2.1 The Reference State

The reference state of the atmosphere has been chosen so that

$$\frac{\partial P_0}{\partial x_3} = -\rho_0 g \tag{3.5}$$

$$\frac{\partial T_0}{\partial x_3} = -\gamma_d \qquad (3.6); \qquad \gamma_d = g/c_p$$

Furthermore the atmosphere is assumed to be a perfect gas so

$$P_0 = R\rho_0 T_0 \tag{3.7}$$

In order to determine fully the reference state, we must choose a reference height $x_3 = h_0$ and two of the three variables P_0, T_0 and ρ_0 at that height. Integration of (3.5), (3.6), (3.7) yields the result

$$\begin{aligned} T_0 &= T_0(h_0)\left[1 - \frac{\gamma_d}{T_0(h_0)}\,(x_3 - h_0)\right] \\ P_0 &= P_0(h_0)\left[1 - \frac{\gamma_d}{T_0(h_0)}\,(x_3 - h_0)\right]^{c_p/R} \\ \rho_0 &= \rho_0(h_0)\left[1 - \frac{\gamma_d}{T_0(h_0)}\,(x_3 - h_0)\right]^{(c_p-R)/R} \end{aligned} \tag{3.8}$$

Note that the pressure P_0, density ρ_0 and temperature T_0 of the reference state are not constant with height as often implied, but their variation is weak and almost linear over height intervals up to a kilometer.

If we require that the reference state be stationary and motionless then it follows from (3.8) and the equation of motions that:

$$\frac{\partial P_0}{\partial x_1} = \frac{\partial P_0}{\partial x_2} = 0 \tag{3.9}$$

$$\frac{\partial^2 T_0}{\partial x_1^2} + \frac{\partial^2 T_0}{\partial x_2^2} = 0 \tag{3.10}$$

Equations (3.8) and (3.9) imply that $P_0(h_0)$, $T_0(h_0)$, $\rho_0(h_0)$ cannot be functions of x_1 and x_2 and hence that the reference state is horizontally homogeneous. The proper choice of h_0, $P_0(h_0)$, $T_0(h_0)$ depends on the problem under consideration, but the perturbation quantitities p, T', ρ' should be small with respect to P_0, T_0, ρ_0 points to the logical choice of space time averages of P and T assigned to some mean height of the flow field. However, in most micrometeorological applications, a convenient choice is to take the time averages of pressure and air temperature average over the lower boundary.

Hence:

$$T' = T - T_0 = T - T(0) + \gamma_d x_3 \ .$$

If we define the potential temperature as

$$\theta = \tilde{T}\left(\frac{\tilde{P}}{1000}\right)^{-R/c_p} \tag{3.11}$$

The primitive equations take the following form:

Continuity Equation:

$$\frac{\partial u_j}{\partial x_j} = 0 \ , \tag{3.12}$$

Momentum Equation:

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = - \frac{1}{\rho(\theta_0)} \frac{\partial p}{\partial x_i} - \frac{\rho(\theta) - \rho(\theta_0)}{\rho(\theta_0)} g_i \delta_{i3} + \nu \frac{\partial^2 u_i}{\partial x_j^2} \ , \text{ and} \tag{3.13}$$

Energy Equation:

$$\frac{\partial \theta}{\partial t} + u_j \frac{\partial \theta}{\partial x_j} = \nu P_r^{-1} \frac{\partial^2 \theta}{\partial x_j^2} \ . \tag{3.14}$$

At this point we have decomposed the three-dimensional fluid mechanics equations into a reference adiabatic state, and a flow field of perturbation about this state.

However these equations are nonlinear, and mathematically arduous to solve. In addition the spatial scale of the smallest motions is very small, and a tractable solution demands some form of spatial averaging. To solve the problem the equations will be ensemble-averaged and the turbulence closure equations will be formulated before finite differencing the set.

3.2.2 Reynolds Decomposition and Closure

In order to examine the basic features of the mean flow, we introduce the Reynolds hypothesis

$$x = \bar{x} + x' \tag{3.15}$$

where x is some perturbation of a primitive variable;

$\bar{x}$ is its ensemble average;

x' is any fluctuations about its ensemble average.

Thus the decomposed dependent quantities are expressed as

$$\begin{aligned} u_i &= \bar{u}_i + u_i, \text{ where } \overline{u_i'} = 0 , \\ P &= \bar{P} + P', \text{ where } \overline{P'} = 0 , \\ \theta &= \bar{\theta} + \theta', \text{ where } \overline{\theta'} = 0 , \text{ and} \\ \rho &= \bar{\rho} + \rho', \text{ where } \overline{\rho'} = 0 . \end{aligned} \tag{3.16}$$

By making these transformations, by selectively ensemble averaging the primitive equations become the following:

<u>Continuity Equations</u>:

$$\begin{aligned} \frac{\partial \bar{u}_j}{\partial x_j} &= 0 , \\ \frac{\partial u'_j}{\partial x_j} &= 0 , \end{aligned} \tag{3.17}$$

Momentum Equations:

$$\frac{\partial u_i}{\partial t} + \bar{u}_j \frac{\partial u_i}{\partial x_j} = - \frac{1}{\rho(\theta_0)} \frac{\partial \bar{p}}{\partial x_i} + \frac{\rho(\bar{\theta}) - \rho(\theta_0)}{\rho(\theta_0)} g_i \delta_{i3} + \nu \frac{\partial^2 u_i}{\partial x_j^2}$$

$$- \frac{\partial}{\partial x_j} \left(\overline{u'_i u'_j}\right) , \tag{3.18}$$

$$\frac{\partial u'_i}{\partial t} + \bar{u}_j \frac{\partial u'_i}{\partial x_j} + u'_j \frac{\partial \bar{u}}{\partial x_j} + u'_j \frac{\partial u'_i}{\partial x_j} - \frac{\partial}{\partial x_j} \left(\overline{u'_i u'_j}\right) =$$

$$- \frac{1}{\rho(\theta_0)} \frac{\partial p'}{\partial x_i} - \frac{\rho(\theta') - \rho(\theta_0)}{\rho(\theta_0)} g_i \delta_{i3} + \nu \frac{\partial^2 u'_i}{\partial x_j^2} , \tag{3.19}$$

Energy Equation:

$$\frac{\partial \bar{\theta}}{\partial t} + \bar{u}_j \frac{\partial \bar{\theta}}{\partial x_j} = \nu P_r^{-1} \frac{\partial^2 \bar{\theta}}{\partial x_y^2} - \frac{\partial}{\partial x_j} \left(\overline{u'_j \theta'}\right) \quad \text{, and} \tag{3.20}$$

$$\frac{\partial \theta'}{\partial t} + \bar{u}_j \frac{\partial \theta'}{\partial t} + u'_j \frac{\partial \theta}{\partial x_j} + u'_j \frac{\partial \theta}{\partial x_j} - \frac{\partial}{\partial x_j} \left(\overline{u'_j \theta'}\right) = \nu P_r^{-1} \frac{\partial^2 \theta'}{\partial x_j^2} . \tag{3.21}$$

The ensemble averaged set of equations (3.20), (3.18), (3.16) lacks the knowledge of the turbulent terms $\overline{u'_i u'_j}$, and $\overline{u'_i \theta'}$. This is the well known closure problem, which can be solved by manipulating the equations governing the functioning terms in such a way as to derive transport equations for the Reynolds stresses: this procedure yields to a set of coupled partial differential equations which can be written as:

$$\frac{D}{Dt} \left(\overline{u'_i u'_j}\right) = - \overline{u'_i u'_k} \frac{\partial \bar{u}_j}{\partial x_k} - \overline{u'_j u'_k} \frac{\partial \bar{u}_i}{\partial x_k} \qquad \text{production terms}$$

$$- \frac{\partial}{\partial x_k} \left(\overline{u'_i u'_j u'_k}\right) \qquad \text{turbulent transport term}$$

$$- \frac{1}{\rho_0} \frac{\partial}{\partial x_i} \left(\overline{p' u'_j}\right) - \frac{1}{\rho_0} \frac{\partial}{\partial x_j} \left(\overline{p' u'_i}\right) \qquad \text{pressure diffusion terms}$$

$$+ \frac{1}{p_0} \overline{p' \left(\frac{\partial u'_i}{\partial x_j} + \frac{\partial u'_j}{\partial x_i}\right)} \qquad \text{return to isotropy term}$$

$$+ \frac{1}{\theta_0} \left(g_i \delta_{i3} \overline{u'_j \theta'} + g_j \delta_{j3} \overline{u_i \theta'}\right) \qquad \text{buoyant production terms}$$

$$+ \nu \frac{\partial^2}{\partial x_k^2} \left(\overline{u'_i u'_j}\right) \qquad \text{molecular diffusion terms}$$

$$- 2\nu \overline{\frac{\partial u'_i}{\partial x_k} \frac{\partial u'_j}{\partial x_k}} \qquad \text{dissipation terms (3.22)}$$

$$\frac{D}{Dt} \left(\overline{u'_i \theta'}\right) = - \overline{u'_j u'_i} \frac{\partial \overline{\theta}}{\partial x_j} - \overline{u_j \theta'} \frac{\partial \overline{u_i}}{\partial x_j} \qquad \text{production terms}$$

$$- \frac{\partial}{\partial x_j} \left(\overline{u_i u_j \theta'}\right) \qquad \text{turbulent transport terms}$$

$$- \frac{1}{\rho_0} \frac{\partial}{\partial x_i} \left(\overline{p' \theta'}\right) \qquad \text{pressure diffusion term}$$

$$+ \frac{1}{\rho_0} \overline{p' \frac{\partial \theta'}{\partial x_i}} \qquad \text{return toward isotropy}$$

$$+ \frac{1}{\theta_0} g_i \delta_{i3} \overline{\theta' \theta'} \qquad \text{buoyant production term}$$

$$+ \nu \frac{\partial^2}{\partial x_y^2} \left(\overline{u'_i \theta'}\right) \qquad \text{molecular diffusion term}$$

$$- 2\nu \frac{\partial u'_i}{\partial x_j} \frac{\partial \theta'}{\partial x_j} \qquad \text{dissipation term (3.23)}$$

$$\frac{D}{Dt} \left(\overline{\theta'^2}\right) = - 2 \overline{u'_j T'} \frac{\partial \overline{T}}{\partial x_j} \qquad \text{production terms}$$

$$- \frac{\partial}{\partial x_j} \left(\overline{u'_j T'^2}\right) \qquad \text{turbulent transport term}$$

$$+ \nu_0 \frac{\partial^2}{\partial x_j^2} \left(\overline{T'^2}\right) \qquad \text{molecular diffusion term}$$

$$- 2\nu \left(\overline{\frac{\partial T'}{\partial x_j} \frac{\partial T'}{\partial x_j}}\right) \qquad \text{dissipation term (3.24)}$$

Equations (3.22), (3.23), (3.24) are solved in the one-dimensional case for the planetary Boundary Layer problem in Chapter 4. However it is important to emphasize the central importance of this set in boundary layer modeling. A more detailed approach of the VARR II turbulence model is presented in Appendix A.

3.2.3 Moisture Transport and Dynamics

The moisture equations have been implemented previously in the model [3]. For completeness we will reiterate briefly the derivation of the equation set governing a moist atmosphere. The main assumptions associated with the use of the virtual temperature are pointed out. An important part of this paragraph is devoted to the Equilibrium cloud microphysics model and its numerical treatment.

3.2.3.1 Reference State Decomposition

The transient equation governing the vapor and liquid density are written taking into account both turbulent transport and processes of evaporation and condensation. However, before going into the detailed equations it is important to derive the mean field equations for the moist atmosphere.

The density of a parcel of moist air is:

$$\tilde{\rho} = \tilde{\rho}_{dry} + \tilde{\rho}_{vap} + \tilde{\rho}_{Liq}$$

Since the density of liquid water is relatively small, it is neglected (typically liquid water is less than 1% of the mass of the fluid). Then we can say that

$$\tilde{\rho} = \frac{\tilde{P}_{dry}}{R_d T} + \frac{\tilde{P}_{vap}}{R_v T} + \frac{(\tilde{P}_{dry} + \tilde{P}_{vap})}{R_d T_v} = \frac{\tilde{P}}{R_d T_v}$$, assuming

that $R_v \tilde{\approx} R_d$. Since $\frac{R_v}{R_d} = 1.6$ this assumption is most easily defended by noting that typically $\rho_v/\rho_D < 0.01$. Given the decomposition above the reference state will be governed by the following equations.

Equation of State:

$$p_0 = \rho_0 R_d T_{v_0} \tag{3.27}$$

The momentum equation for the adiabatic atmosphere becomes the hydrostatic equation:

$$\frac{dp_0}{dz} = -\rho_0 g \tag{3.28}$$

By making the assumption that the heat capacity for a moist gas, c_p^{moist}, is that of a dry gas, c_p, the first law of thermodynamics for an unsaturated adiabatic process yields the result:

$$\frac{dT_{v_0}}{dz} = -\frac{g}{c_p} = -9.76° \mathrm{C/Km}$$

It is to be noted that the assumption of neglecting the liquid water mass in a parcel of moist air is important in this derivation of the reference state equations. It would not have been possible to carry this derivation if this assumption was to be relaxed.

In the same manner as for the dry atmosphere the fluid flow and thermodynamic equation can be derived using the virtual temperature concept and the latent heat release term.

Again, from the primitive equations we obtain the following results:

Continuity Equation:

$$\frac{\partial u_j}{\partial x_j} = 0$$

Momentum Equation:

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = - \frac{1}{\rho_0} \frac{\partial p}{\partial x_i} + \frac{T_v}{T_{v_0}} g_i \delta_{i3} + \frac{\mu_0}{\rho_0} \frac{\partial^2 u_i}{\partial x_y^2} \text{ , and} \tag{3.27}$$

Energy Equation:

$$\frac{\partial T_v}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = \nu P_r^{-1} \frac{\partial^2 T_v}{\partial x_y^2} - \frac{L}{\rho c_p} \left(\frac{D\rho}{Dt}\right)_{phase} \text{ ,} \tag{3.28}$$

where L is the latent heat of condensation or evaporation.

The latent heat term $\left(\frac{D\rho}{Dt}\right)_{phase}$ is given more attention in the consideration of the Cloud microphysics model.

Again as in the dry atmosphere, we define the virtual potential temperature by the relationship:

$$\tilde{\theta}_v = \tilde{T}_v \left(\frac{1000}{\tilde{p}}\right)^{R_d/c_p^{moist}} \tag{3.29}$$

When we use this variable, the moist adiabatic lapse rate becomes

$$\frac{d\theta_{v_0}}{dz} = 0 \quad , \tag{3.30}$$

which says that the virtual potential temperature is constant in a reference state. Again neglecting the pressure perturbation and using T_v instead of θ_v the primitive equations yield the form:

Continuity Equation

$$\frac{\partial u_j}{\partial x_j} = 0 \quad , \tag{3.31}$$

Momentum Equation:

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = - \frac{1}{\rho(\theta_0)} \frac{\partial p}{\partial x_i} - \frac{\rho(\theta_v) - \rho(\theta_v)}{\rho(\theta_{v_0})} g_i + \nu \frac{\partial^2 u_i}{\partial x_j^2} \text{, and} \tag{3.32}$$

Energy Equation:

$$\frac{\partial \theta_v}{\partial t} + u_j \frac{\partial \theta_v}{\partial x_j} = - \nu P_r^{-1} \frac{\partial^2 \theta_v}{\partial x_j^2} - \frac{L}{Pc_p} \left(\frac{D\rho_{vap}}{Dt}\right)_{phase} \quad . \tag{3.33}$$

3.2.3.2 Mass Transport Equations

Mass transport equations can be stated for liquid water, water vapor, radioactive pollutants, chemical pollutants, etc. We focus our interest on liquid water and vapor. In the notation used previously, the transport equations can be written as

$$\frac{\partial}{\partial t}\rho_{vap} + u_j \frac{\partial \rho_{vap}}{\partial x_j} = \nu S_{c\,vap}^{-1} \frac{\partial^2}{\partial x_j^2}\rho_{vap} + \left(\frac{D}{Dt}\rho_{vap}\right)_{phase} \quad \text{, and} \tag{3.34}$$

$$\frac{\partial}{\partial t}\rho_{Liq} + u_j \frac{\partial \rho_{Liq}}{\partial x_j} = \nu S_{c_{vap}}^{-1} \frac{\partial^2}{\partial x_j^2}\rho_{Liq} + \left(\frac{D}{Dt}\rho_{Liq}\right)_{phase} \quad , \tag{3.35}$$

where $S_{c_i}^{-1} = \dfrac{D\rho_i}{\mu_i}$

Notice that no reference state is used in the transport equation.

3.2.4 Reynolds Decomposition

As with the dry atmosphere we can decompose the primitive equations into two sets, a set of mean field equations and a set for the fluctuating terms. Each primitive variable can be decomposed into the ensemble-averaged and fluctuating parts as follows:

$$\begin{aligned}
p &= \bar{p} + p' \ , \\
\theta &= \bar{\theta} + \theta' \ , \\
\rho &= \bar{\rho} + \rho' \ , \\
u_j &= \bar{u}_j + u_j' \ , \\
\rho_{vap} &= \bar{\rho}_{vap} + \rho_{vap}' \ , \text{ and} \\
\rho_{Liq} &= \bar{\rho}_{Liq} + \rho_{Liq}' \ .
\end{aligned} \tag{3.36}$$

By performing the proper averaging and manipulating with the different primitive equations one can show that the flow equations can be written as follows:

Continuity Equation:

$$\frac{\partial \bar{u}_j}{\partial x_j} = 0 \ , \tag{3.37}$$

Momentum Equation:

$$\frac{\partial}{\partial t} \bar{u}_i + \bar{u}_j \frac{\partial \bar{u}_i}{\partial x_j} = \frac{-1}{\rho(\theta_{v_0})} \frac{\partial \bar{p}}{\partial x_i} - \frac{\rho(\theta_v) - \rho(\theta_{v_0})}{\rho(\theta_{v_0})} g_i + \nu \overline{\frac{\partial^2 u_i}{\partial x_j^2}}$$

$$- \frac{\partial}{\partial x_j} (\overline{u_i' u_j'}) \quad , \text{ and} \tag{3.38}$$

Energy Equation:

$$\frac{\partial \bar{\theta}_v}{\partial t} + \bar{u}_j \frac{\partial \bar{\theta}_v}{\partial x_j} = \nu P_r^{-1} \frac{\partial^2 \bar{\theta}_v}{\partial x_j^2} - \frac{\partial}{\partial x_j} (\overline{u_j \theta_v'}) - \frac{L}{\rho(\bar{\theta}_v) c_p} \left(\frac{D}{Dt} \bar{\rho}_{vap}\right)_{phase} . \tag{3.39}$$

The transport equations (3.34),(3.35) will then yield the form

Vapor Equation:

$$\frac{\partial}{\partial t} \bar{\rho}_{vap} + \bar{u}_j \frac{\partial}{\partial x_j} \bar{\rho}_{vap} = \nu S_{c_{vap}}^{-1} \frac{\partial^2}{\partial x_j^2} \bar{\rho}_{vap} - \frac{\partial}{\partial x_j} (\overline{\rho_{vap}' u_j'})$$

$$+ \left(\frac{D}{Dt} \bar{\rho}_{vap}\right)_{phase} \quad , \text{ and} \tag{3.40}$$

Liquid Equation:

$$\frac{\partial}{\partial t} \bar{\rho}_{Liq} + \bar{u}_j \frac{\partial}{\partial t} \bar{\rho}_{Liq} = \nu S_{c_{Liq}}^{-1} \frac{\partial^2}{\partial x_y^2} \bar{\rho}_{Liq} - \frac{\partial}{\partial x_j} (\overline{\rho_{Liq}' u_j'})$$

$$+ \left(\frac{D}{Dt} \bar{\rho}_{Liq}\right)_{phase} \quad . \tag{3.41}$$

In the plume model the transport of turbulence is performed using the k-σ model (see Appendix A). The ability of such a model to describe atmospheric turbulence has yet to be demonstrated. This aspect of the model is discussed in the chapter concerning conclusions and recommendations.

3.3 Equilibrium Cloud Microphysics Model

The main assumptions made in this model are the following:

* water vapor and liquid water are always in equilibrium
* surface tension and surface curvature of the liquid droplets are ignored, that is phase equilibrium over a flat surface of water is assumed to exist.

A phase diagram (p,T) illustrates the degrees of freedom we allow our system to have. The saturation line between the liquid and vapor phases represents the only loci of points that the vapor pressure and temperature may take.

In order to solve this problem mathematically, it is important to model this saturation line. It is readily simulated by the magnus formula for which the derivation is given in Appendix B. It yields the result

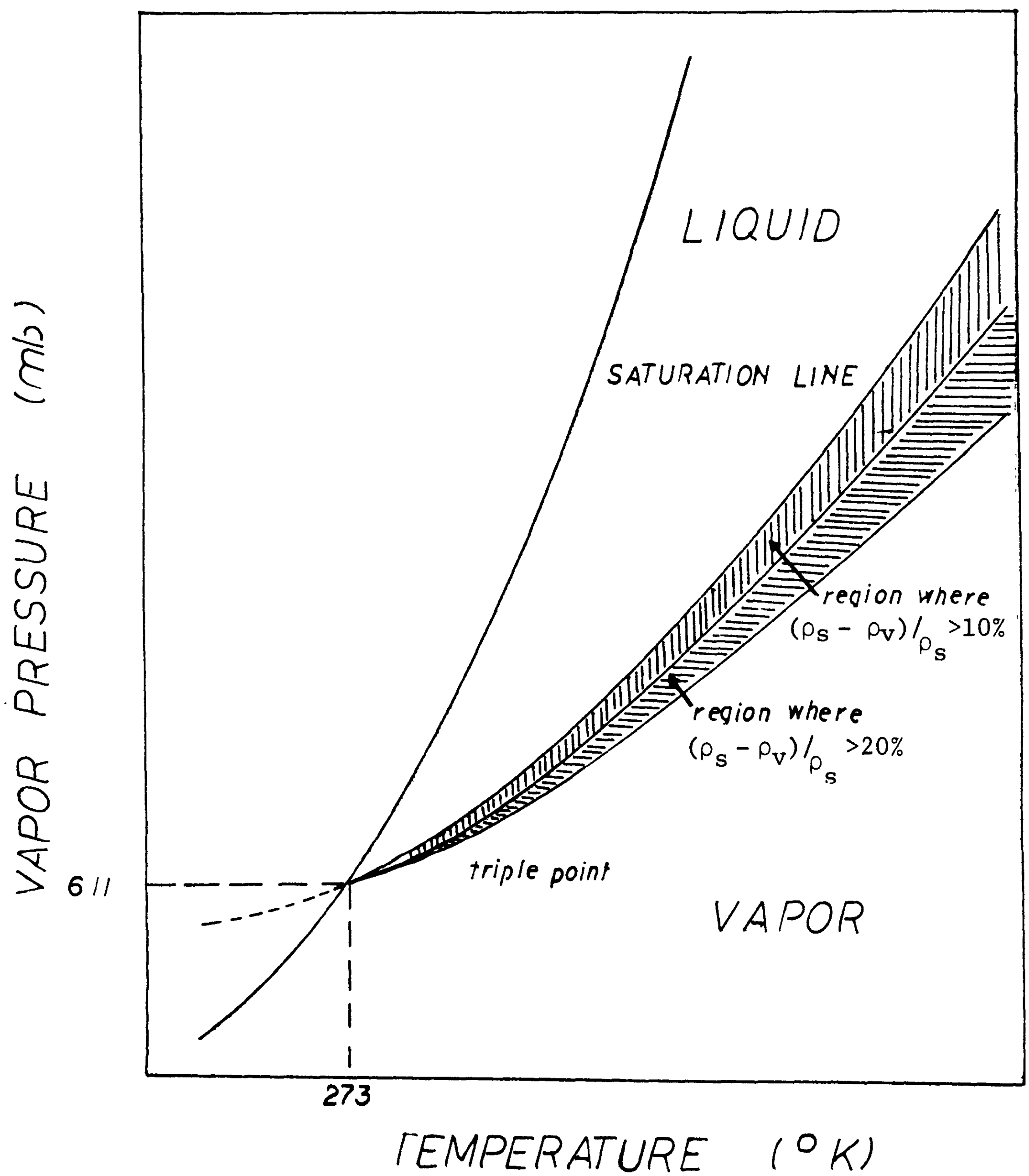


FIGURE 3.1

Phase Diagram for Water Substance

$$\log_{10} p_{sat} = - \frac{2937.4}{T} - 4.9283 \log_{10} T + 23.558 \qquad (3.42)$$

where p is the saturation pressure (mbar), and T is the saturation temperature (°K). The magnus formula gives the temperature and pressure dependence of the saturation line.

In the simulated flows, as water vapor and liquid are transported downwind they are actively mixed with the surrounding air. This process results in a situation where each individual computational cell is in a non-equilibrium moisture state. However, it is required that the cloud microphysics model restore equilibrium conditions within the cell. This is done by allowing the condensation of vapor and evaporation of liquid water. The heat released or absorbed is accounted for in the energy equation.

3.3.1 Latent Heat Source Term

At each time step and in each cell, the latent heat source term is calculated depending whether a change of phase takes place. As shown in the energy equation the latent heat source or sine term is calculated from

$$\text{Latent Heat Release} \left[\frac{\text{Joules}}{\text{Kg. sec}}\right] = - \frac{L}{\rho(\theta_v) c_p} \left(\frac{D}{Dt} \rho_{vap}\right)_{phase} \qquad (3.43)$$

where L is the latent heat of vaporization, and is taken to be equal to 2501 $^{KJ}/_{Kg}$.

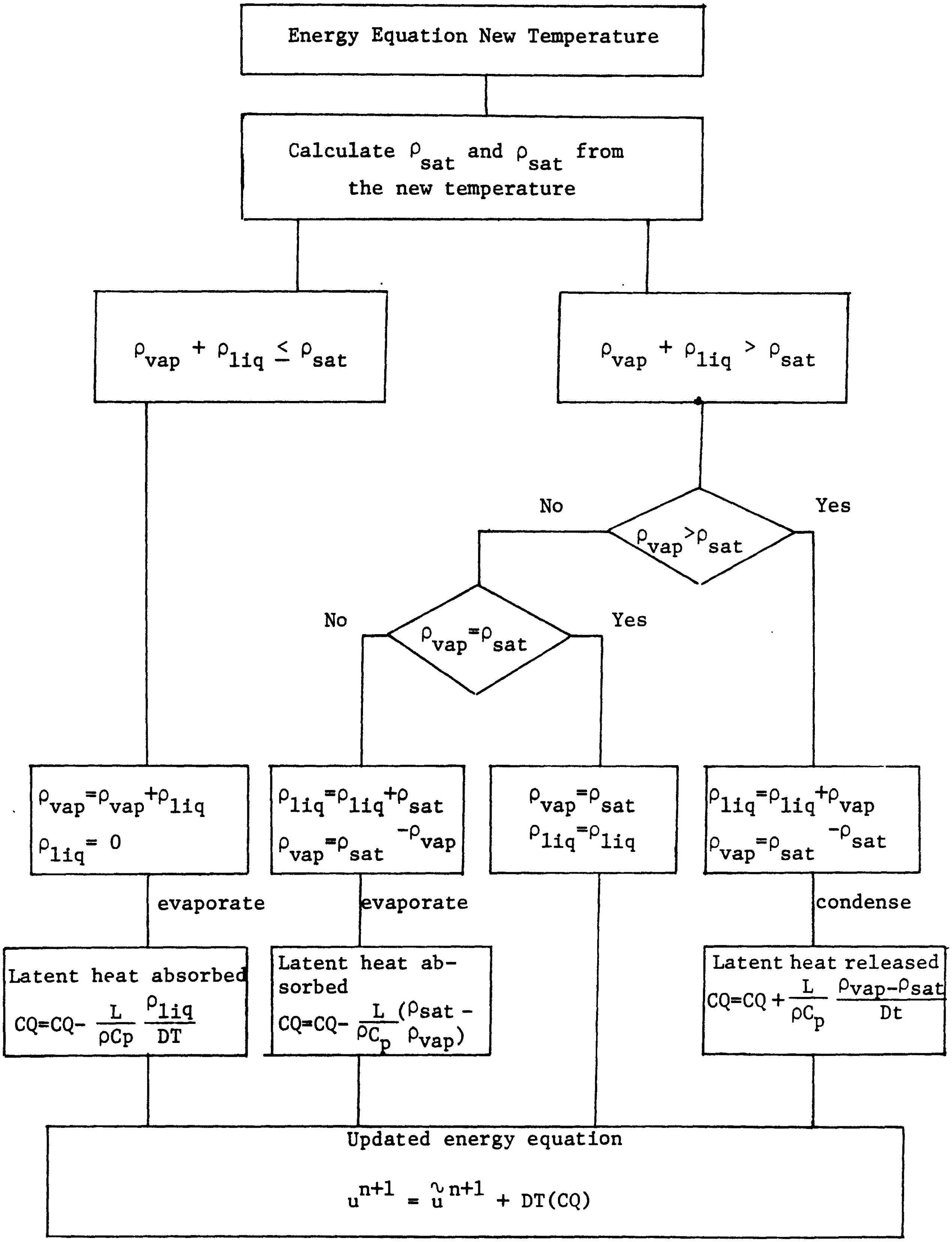


FIGURE 3.2

Logic Diagram for the Equilibrium Moisture Calculation in a Single Cell During a Single Timestep

For subsaturated conditions moisture is treated as a simple conservative property i.e., vapor and liquid water densities are transported according to Equations (3.40) and (3.41).

Saturation and condensation are encountered when the mixing ratio $\left(\frac{m_V}{m_A}\right)$ of the mixed air-water vapor parcel is larger than the solution mixing ratio for the corresponding temperature. Fig. (3.2) describes the pertinent mechanisms involved.

3.4 Solution Methodology

3.4.1 The Buoyant Plume Model Fluid Mechanisms Algorithm

The model uses the original simplified marker and cell method (SMAC) to solve the basic two-dimensional fluid mechanical equations of continuity, momentum, and energy for a Boussinesq fluid. The VARR-II code [28] provided the framework for model development. The basic SMAC method algorithm has not been changed. However, pollutant (passive) and moisture transport equations have been implemented in addition to the initial set [3].

The buoyant plume model computing mesh solves for each individual cell, and at each time step, the hydrodynamic, the thermodynamic equations and transport equation for moisture, for positive pollutants and for two closure variables; the turbulent kinetic energy (q) and the turbulent kinematic viscosity σ.

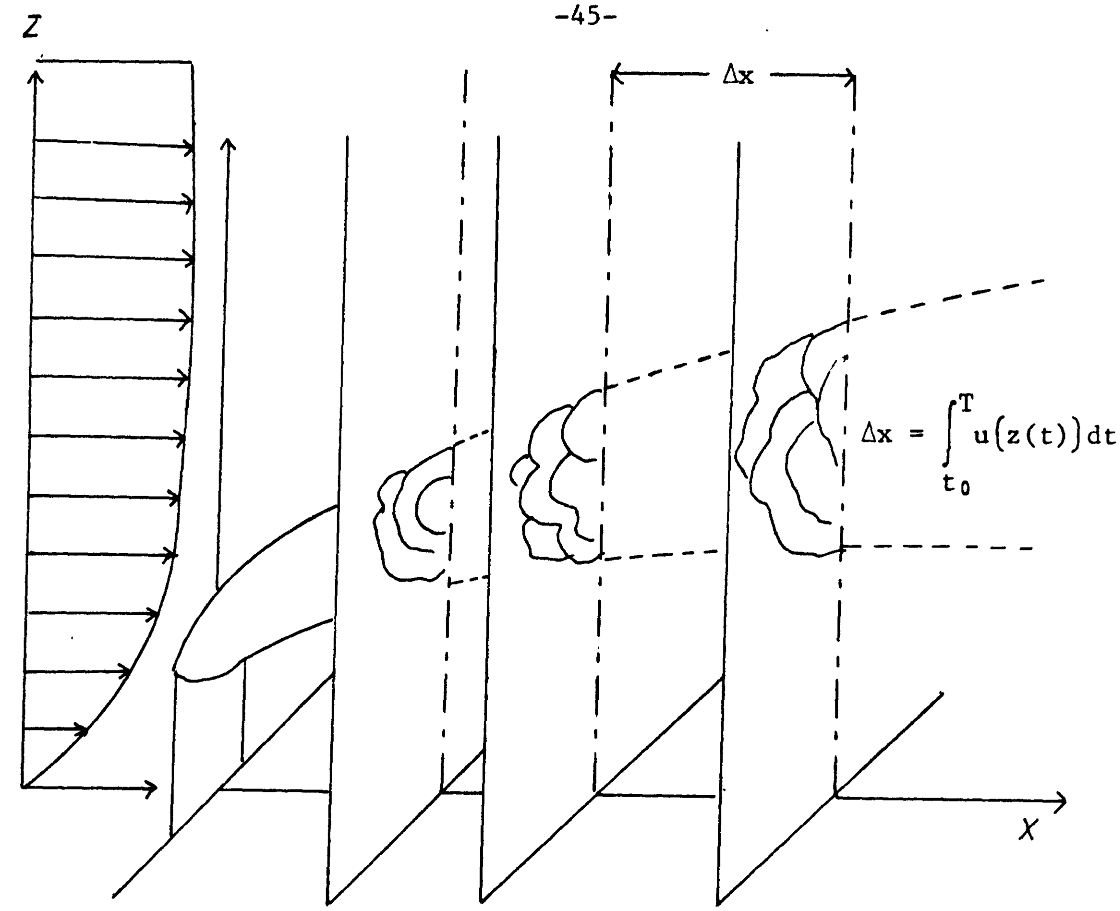
The model solves directly the primitive variables without going either to a non-dimensional formulation or to the transformation to vorticity stream function variables.

The solution of the set is divided into two parts, in the first, the momentum, turbulence and specific internal energy are computed as intermediate values which are later updated during the pressure iteration to assure that the incompressibility condition $\nabla \bar{u} = 0$ is satisfied. The turbulence kinetic energy (q), the turbulence kinematic viscosity (σ), the specific energy (I), the vapor density (ρ_V), the liquid density (ρ_{Liq}) and the pollutant density (χ) are also updated in the second part with the updated velocities which satisfy the continuity equation.

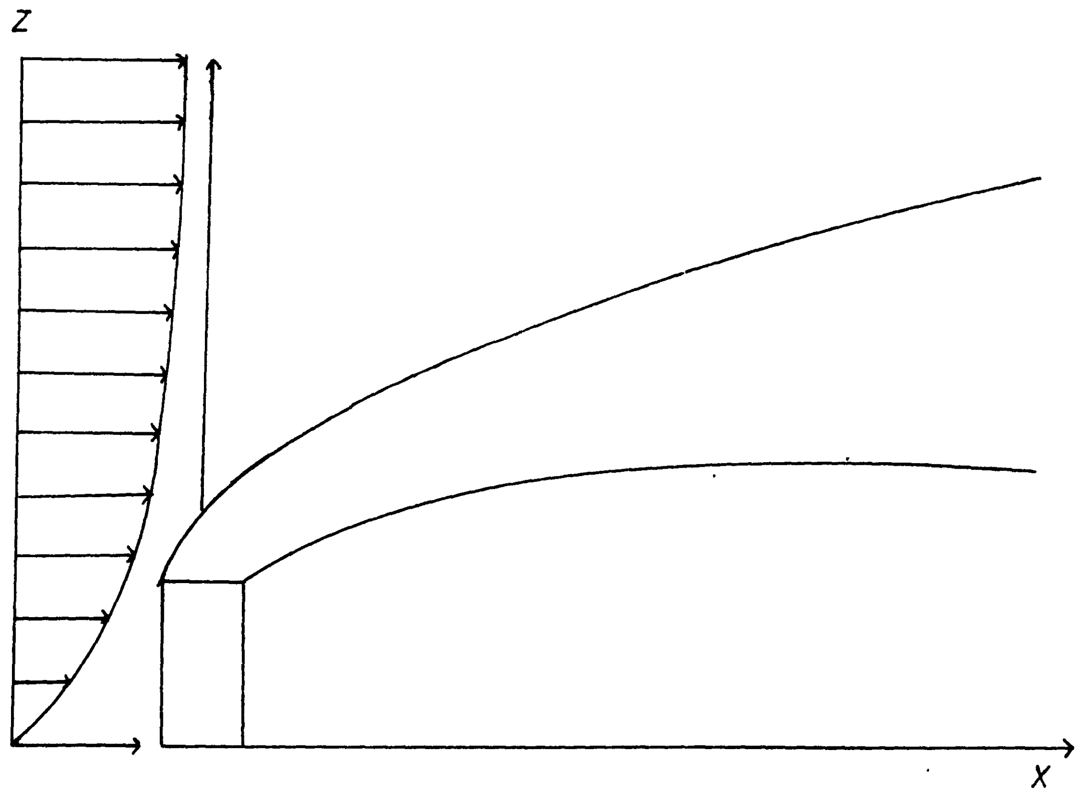
3.4.2 Orientation of the Computer Mesh

The two-dimensional mesh is oriented in the crosswind alignment (see Fig. 3.3.a).

The crosswind alignment takes advantage of the vortex symmetry, and leads to the simulation of only half the plume cross-section. However the greatest advantage of this scheme is that one can reconstruct the three-dimensional picture by "cutting slices" into the plume. This results from the fact that in the downwind Lagrangian translation of the computational mesh the time variable becomes a surrogate for the downwind position x, where



a) Crosswind Alignment



b) Downwind Alignment

FIGURE 3.3

Mesh Alignment and Reconstruction of the Three-Dimensional Plume

$$x = \int_0^t u[z(t)]dt \ .$$

The singular disadvantage of the crosswind alignment scheme is that it cannot explicitly calculate the shear-produced turbulence of the mean wind field since the mean wind has no component in the y-z plane.

3.4.3 The Moisture Model

In modeling visible plumes it is important to account properly for the temperature field. This is not an easy task when moisture effects are included. For consideration of plume thermodynamics after leaving the tower one needs to understand the moist air thermodynamics. The equations for saturation water vapor content of air, and the physical properties of air-water vapor mixtures can be used to indicate, for any temperature, pressure, moisture content, etc., whether or not a plume will be saturated and whether condensation or evaporation of cloud droplets will occur.

The thermodynamic changes that can take place as a cooling tower plume mixes with ambient air are conveniently illustrated on a psychrometric chart, which is a graph of temperature versus water content of air. The curve on the psychrometric chart defines the saturated state of moist air, and comparison of the temperature-water content coordinates of a plume-air mixture to states on the saturation curve readily depicts the excess water (condensed cloud droplets) or saturation deficit of the mixture. A good understanding of the physical phenomena involved in modeling visible plumes is important before undertaking any mathematical development. Fig. 3.4 shows the important mechanisms.

Point A in Fig. 3.4 corresponds to a saturated state (i.e. which could represent air leaving a cooling tower). Points B, C, and D are possible atmospheric conditions. If we assume first that the atmosphere is at condition B, and if we assume homogeneous mixing of effluent air from the cooling system with ambient air to occur then the thermodynamic state of the plume must lie along the line AB. Increasing distances from A towards B represent increasing dilution of the effluent. In the region of the diagram between the intersections of AB and the saturation curve (from A to E), the air mixture is supersaturated: the total water density in the mixture is greater than the vapor saturation density for the mixture temperature. Thus, condensation will occur and visible plume will exist. When the effluent-air mixture line lies in the unsaturated portion of the diagram (from E to B), the mixture is unsaturated and cloud will evaporate.

It can be seen that for an atmospheric state such as B, some visible plume must always occur. Its physical dimensions depend upon the distance the plume travels from the cooling system before it is diluted to the state E, where the cloud can evaporate. For a state of

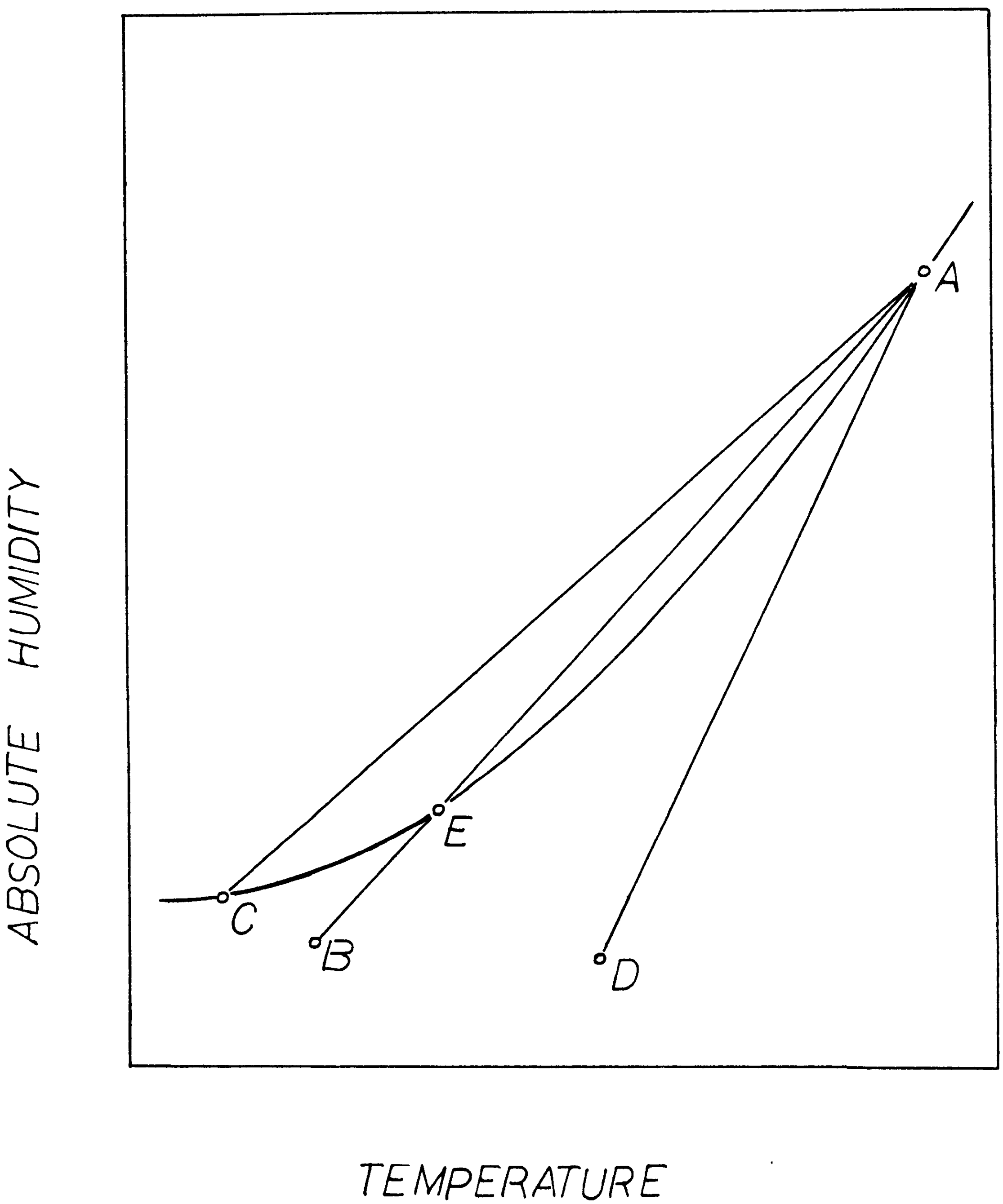


FIGURE 3.4

Saturation Absolute Humidity versus Temperature the ambient atmosphere such as C, where the air is already saturated, condensation will exist in the entire plume, and it would, in principle, extend downwind indefinitely. On the other hand, if the atmosphere is sufficiently warm and dry, as at point D, the mixture of plume and air would be everywhere unsaturated, and no visible cloud could exist.

The amount of liquid water condensed in a plume can be estimated from the diagram by comparing the water density of the mixture to the saturation density. The water excess over saturation is the liquid water that will make up the cloud droplets. Actually, the mixture line between A and E is slightly curved, resulting in somewhat lower liquid water content than would be inferred from the straight line case. The curvature is due to the latent heat of condensation. When the mixture is super-saturated and condensation occurs, heat is released, so the resulting mixture has a higher temperature than that given by simple mixing.

The moist plume model developed in the work calculates the concentration of plume constituents (moisture, pollutant, turbulence) for a point of interest by the water transport equations (3.40, 3.41). The model simulates also the saturation line, taking into account disturbances in the temperature field due to the release of the latent heat of evaporation. Given these two values the model determines whether or not these concentrations result in a saturated mixture. The end of the visible plume is commonly taken as the distance from the tower where the water vapor concentration decreases to values below the saturation value. The model does not include the effect of droplet growth and dynamics (Wigley [29])

In a previous version [1] of the moisture model, the water state in a cell is calculated explicitly at the instant $t = (n+1)\,\delta t$ in terms of the moisture thermodynamic state at the previous instant ($t = n\delta t$) and the change in moisture density during the most recent time step. This is done by calculating the virtual potential temperature as:

$$\theta_v^{n+1} = \theta_v^n + \frac{(\rho_v^n - \rho_s^n)L}{\rho^n c_p^n} \tag{3.44}$$

where ^{n} and c_p^n are determined by the passive conservation of moisture equation. Use of equation 3.44 is equivalent to saying

$$\theta_v^{n+1} = \theta_v^n + \left.\frac{\delta\theta_v}{\delta\rho}\right|_{t=n\delta t}\left(\rho^{n+1} - \rho^n\right) \tag{3.45}$$

This treatment provides a result which is imcompatible with the energy conservation equation which predicts an internal energy for the air-moisture mixture in the cell which is inconsistent in general with the temperature, θ_v^{n+1}, predicted by (3.44).

The discrepancy arises from the fact that the latent heat released by condensation of vapor is not taken into account by the energy equation. This results in oscillation of the temperature field.

In the treatment of this work (see Fig. 3.5) at each time step each cell is tested for its water composition. The moisture-phase composition and the virtual potential temperature are made compatible with the moisture equilibrium condition by allowing a cell either to condense or evaporate in order to restore equilibrium.

The amount of water that changes phase is obtained through the Claudius-Clapeyron equation which gives the slope of the condensation line (Fig. 3.6)

$$\left(\frac{\partial\rho}{\partial T}\right)_{\text{phase}} = - \rho \frac{c_p}{L} , \tag{3.46}$$

where ρ is the gas phase density (air + vapor + liquid). The intersection of the condensation line with the saturation line yields the saturation temperature after evaporation or condensation has taken place.

The following integration scheme has been used. At time $t = n\delta t$ a plume cell is saturated, with a saturation density ρ_{s1} and temperature T_1. Through convection and diffusion the thermodynamic state of the cell, at $t = (n+1)\delta t$, is given by its vapor density and temperature (ρ_2, T_2)(see Fig. 3.5.)

The condensation line is given by the relationship:

$$\rho_{\text{cond}} = - \frac{\rho c_p}{L} (T - T_2) + \rho_{v2} \tag{3.44}$$

The saturation line is given by the magnus formula (see Appendix B):

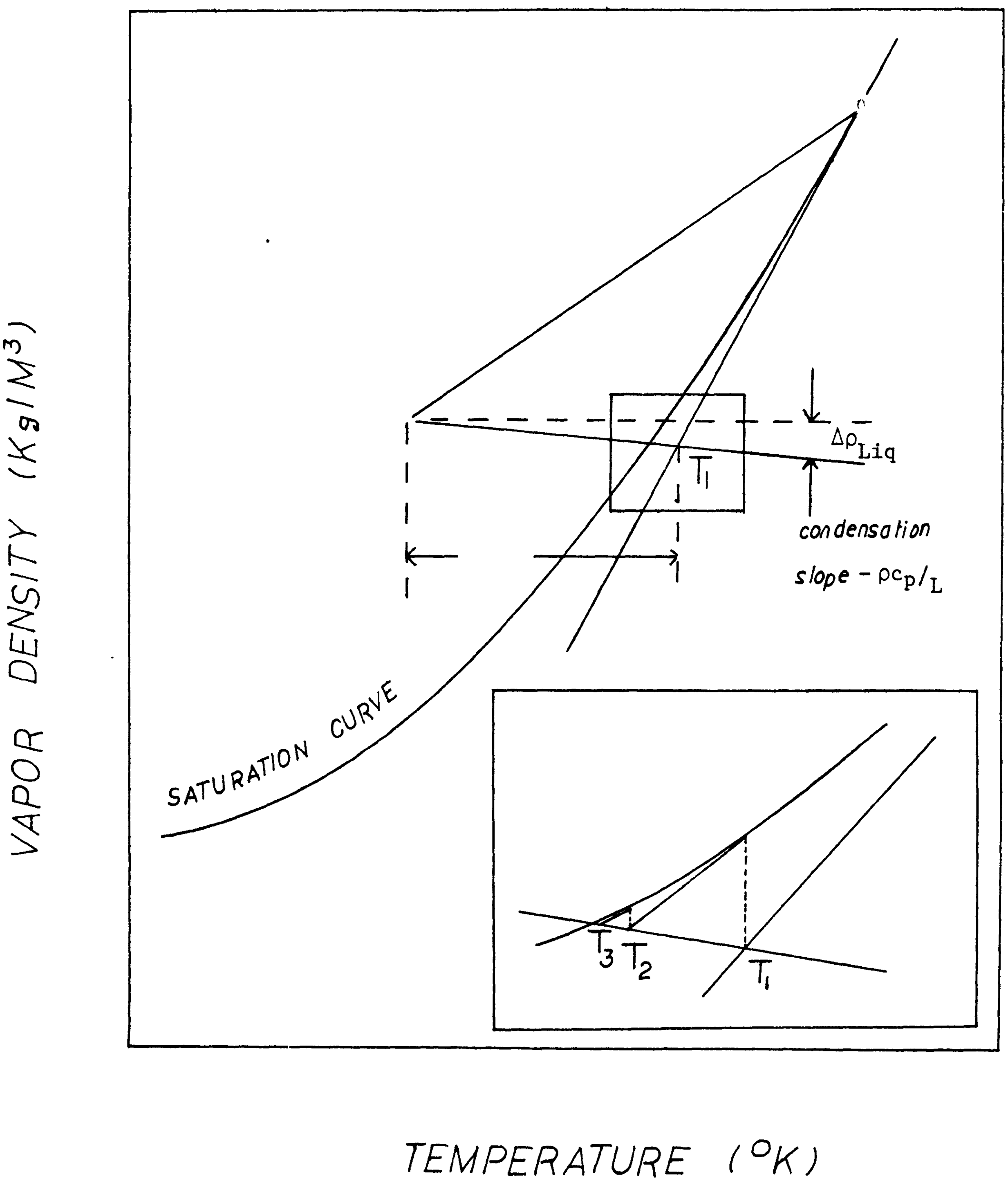


FIGURE 3.5

Integration Scheme for the Implicit Moisture Treatment

$$\rho_s = \rho \frac{0.61}{p} \ell_s(T) \quad . \tag{3.45}$$

Then, solving

$$\rho_{condensation}(T) = \rho_s(T) \tag{3.46}$$

would yield the final temperature. This procedure requires successive iterations in each cell, and integrations of transcendental expressions.

A different and more efficient algorithm is to solve analytically for the temperature using the additional knowledge of the initial ($t = n\,\delta t$) thermodynamic state (ρ_{s1}, T_2).

The intersection of the condensation line with the slope of the saturation line at point (1) is given as (see Fig. 3.5).

$$T_1 = \frac{\left(\rho_{v_2} - \rho_{s1}\right) + \left(\rho'_{s1} T_1 + \rho \frac{c_p}{L} T_2\right)}{\left(\rho'_{s1} + \rho \frac{c_p}{L}\right)}$$

where ρ and c_p are quadratively fitted from air property data (see Table 3.1) as functions of temperature.

Given this temperature, a better approximation (T_2) can be obtain obtained by using the same algorithm. Successive iterations yield a very accurate final temperature. This algorithm is used in the plume model of this work.

I	SYMBOL	PROPERTY	UNITS	CONSTANTS		
				A_I	B_I	C_I
1	ρ	DENSITY	$Lb_m \cdot ft^{-3}$	2.0×10^{-7}	-1.78×10^{-4}	0.086394
2	I	INTERNAL ENERGY	$Lb_m^{-1} \cdot BTU$	4.3×10^{-6}	1.71×10^{-1}	78.357
3	ν	DYNAMIC VISCOSITY	$Lb_m \cdot ft^{-1} \cdot sec^{-1}$	-1.0×10^{-6}	1.92×10^{3}	1.0932
4	K	THERMAL CONDUCTIVITY	$BTU \cdot ft^{-1} \cdot sec^{-1} \cdot {}^\circ R^{-1}$	0	2.59×10^{-5}	0.01313
5	C_p	HEAT CAPACITY	$BTU \cdot Lb_m^{-1} \cdot {}^\circ R^{-1}$	0	-2.00×10^{-6}	0.24008

$$\text{PROPERTY } I = A_I (T-460)^2 + B_I (T-460) + C_I$$

TABLE 3.1

Property Values of Air

3.4.4 Buoyancy Correction in Turbulence Model

The turbulence model in the fluid dynamics portion of the basic plume model uses coupled conservation equations* for turbulence kinetic energy (q) and turbulence viscosity (σ) to provide the momentum equation with a value of turbulent eddy viscosity. In the original version the basic equations do not account for the effects of buoyancy on turbulence. When turbulence equations are formulated taking buoyancy into account an additional source term is introduced into each of the equations as follows:

Equation	Additional Source Term
q	$g \langle p'w' \rangle$
σ	$g \frac{\sigma}{q} \langle p'w' \rangle$

Using the turbulent Prandtl number, and Boussinesq approximations these relationships are transformed as

Equation	Additional Source Term	
q	$- g \frac{\rho_0}{\sigma_0} \frac{\sigma}{Pr} \frac{\delta\bar{\theta}}{\delta z}$	(3.49)
σ	$- g \frac{5\rho_0}{\theta_0} \frac{1}{Pr} \frac{\sigma^2}{q} \frac{\delta\bar{\theta}}{\delta z}$	(3.50)

* see Appendix A

It is seen that the effect of these is turbulent suppression under stable conditions of stable stratification $\left(\frac{\delta\theta}{\delta z} > 0\right)$ and turbulent enhancement under unstable stratification $\left(\frac{\delta\theta}{\delta} < 0\right)$. In some cases this effect is significant.

3.5 Mesh Initialization

3.5.1 Introduction

The plume model requires the input of seven vertical data profiles. Of these seven profiles, five serve to specify upwind boundary conditions, the wind speed is needed by the statistics package, and the pressure is needed by the equilibrium moisture thermodynamics (see Table 3.2). This part of the work has been given considerable emphasis since the prescription of boundary conditions is critical in the modeling of visible plumes. Each one of the discrete values comprising the different profiles must be compatible with the general cell mass, energy and momentum conservation to which it is prescribed. This condition is inherent to the parabolic nature of the problem being simulated. Another important consideration is related to the visible plume rise. In order to obtain a good spatial resolution of the plume it is important that the height increment be as small as possible. However, this can be incompatible with the conservation laws, or with the formulation of the numerics, since one is constrained economically to use of roughly a twenty-by-twenty mesh, or with both of them. There is no systematic way of solving this problem and each case must be analyzed individually. Therefore, two different approaches have been taken. The first consists of "carrying" the plume, by an integral entrainment model, to a point where it is bent over, and then by using the values of the

TABLE 3.2

REQUIRED INPUT PROFILES

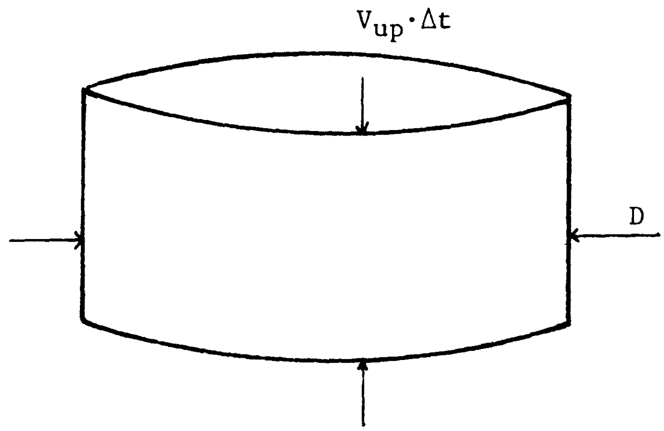
virtual potential temperature	^{o}F
water vapor density	lb_m/ft^3
cloud liquid water density	lb_m/ft^3
eddy viscosity	ft^2/sec
turbulence kinetic energy	ft^2/sec^2
mean wind speed	ft/sec
hydrostatic pressure	millibars

thermodynamic and hydrodynamic variables to initialize the turbulent buoyant plume model. The second approach uses the tower operating parameters to directly initialize the plume model. In this paragraph we first expose the problems related to the incompatabilities with the different conservation laws which arise in initializing a problem. We then describe the integral entrainment model approach to initialization, and the entrainment model itself. Finally each individual profile is given consideration with special attention to the liquid water content of a plume at the exit of the cooling tower. This is because liquid water has an important effect on plume visibility.

3.5.2 Initialization and Conservation Laws

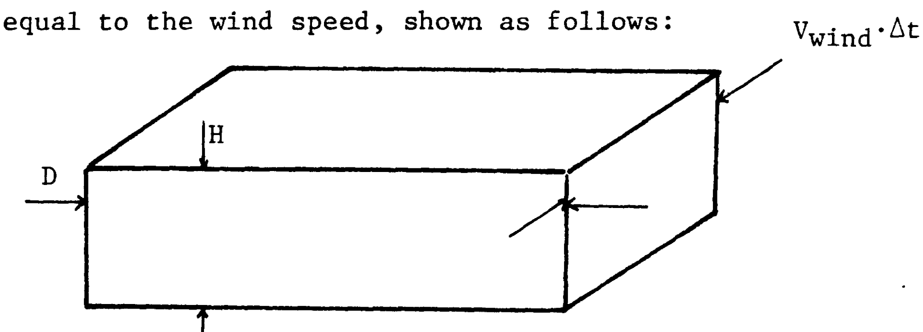
In modelling of any physical problem it is important to preserve the conserved quantities unaltered. The conserved quantities in our case, are energy, momentum, water vapor and liquid water mass release released from the cooling tower. In order to maintain these quantities constant in the simulation it is important to initialize them properly. This is done at the expense of the spatial resolution of the visible plume. In the summer the plume rises only a few stack heights above the exit, while the height of the simulation cells is initialized with a minimum value close to $\frac{1}{2}$ of the stack height. To be more specific, let us consider the following case.

The natural volume, V, into which the plume is released during a time step, Δt, of flow is shown below;



where D is the diameter of the cooling tower and V_{up} the updraft velocity.

The simulation volume is a box that has a width equal to the diameter of the stack, a height equal to the updraft velocity times Δt and a depth equal to the wind speed, shown as follows:



where $V = D.\ H.\ V_{wind}.\ \Delta t.$

Thus in order to keep the energy, momentum, vapor and liquid content constant in the initialization, the two volumes must be equal, i.e.:

$$D.H.V_{wind.}\Delta t = \frac{\pi D^2}{4}.V_{up.}\ \Delta t \quad , \text{or}$$

$$H = \frac{\pi D}{4}\frac{V_{up}}{V_{wind}} \sim \frac{\pi D}{4} = \frac{P}{4} \quad .$$

Upon using parameter values typical of practical cases one obtains the result $H \sim 100$ meters $\simeq$ stack height/2 . To illustrate these points let us consider the following two cases.

In the summer, the atmosphere typically possesses a large saturation deficit which limits the plume length, and a relatively small buoyancy due to small differences in temperature between the tower exit and the ambient atmoshere. This results usually in a plume that rises only few stack heights.

Given the constraint of the cell height in a simulation ($H_{min} \simeq \frac{1}{2}$ stack height) the resolution of the plume is poor. Howerver, this is not the only difficulty, for by choosing a smaller height increment one is limited by the number of cells available in the simulation (20). In addition, by keeping the width of a simulation cell constant and equal to the radius of the tower, one is bound to use more cells in the vertical direction, overpredicting the initial plume rise. If the condition on the cell width is relaxed, very long cells must be used which can alter the actual "geometry" of the plume to very unrealistic shapes.

A solution to this problem is to "carry" the plume to a point where the resolution of the plume height is no longer critical. This

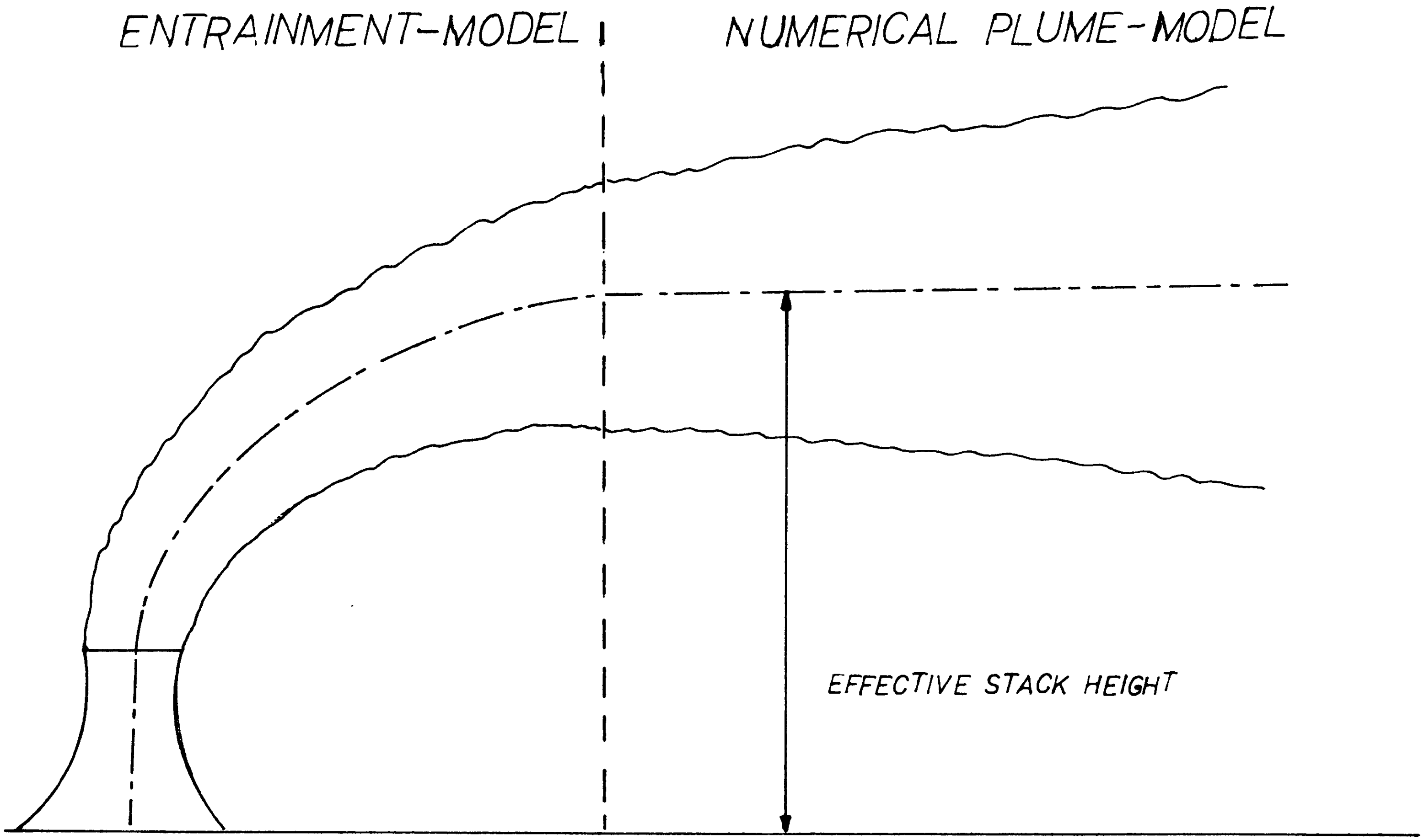


FIGURE 3.6

Division of the Plume

is achieved by using an integral entrainment model to transport the plume to an effective stack height (see Fig. 3.6) given by the following relation:

$$H_{eff} = H_{stack} + L_b$$

where L_b is the buoyancy length and H_{stack} is the stack height. The buoyancy length is the radius of curvative near the stack exit of a pure buoyant plume with negligible initial momentum [30,31].

$$L_b = \frac{g\,Q}{\pi\,\rho_i c_p\,T\,V^3}$$

where g is the acceleration of gravity,

Q is the heat flux of the stack effluent,

$\rho_i c_p$ is the heat capacity per unit volume,

T is the absolute temperature of the atmosphere at the stack exit, and

V is the mean cross-wind speed.

In the winter the saturation deficit of the atmosphere is typically quite low, thus, a very small amount of water would be sufficient to saturate an air parcel. In addition the temperature difference between the tower exit and the ambient atmosphere is usually relatively large, therefore leading to very high and long plumes. It is therefore the rapid mixing of air at the exit of the tower which allows few cells to be initialized in such a way that is compatible with the conservation laws. In this case also, the cell height required by the same conservation laws is not incompatible with the resolution necessary in such an analysis.

3.5.3 The Entrainment Model

3.5.3.1 Introduction

The entrainment model approach for warm atmospheres avoids the difficulties of resolution of the plume near the stack, and predicts accurately average plume properties which are internally consistent and in agreement with the fundamental conservation laws. A version of the Winiarski and Frick [32] model that is compatible with our turbulent plume model has been made available to give the thermodynamic and the hydrodynamic profiles required. This approach starts the simulation with a Lagrangian formulation, where the trajectory of a group of particles is traced in time. This initial plume puff gains mass as ambient fluid is entrained and mixed within it, but once entrained the new mass becomes an indistinguishable part of the plume puff. In the simplest version, the plume is assumed to be a cylindrical segment whose radius grows as mass is entrained (see Fig. 3.9).

3.5.3.2 Description of the Model

Among the basic phenomena which govern plume behavior are the following:

1) Momentum transfer from the wind to the plume,

2) Entrainment and dilution of plume properties due to mixing of ambient air,

3) Buoyant acceleration, and

4) Moisture effects.

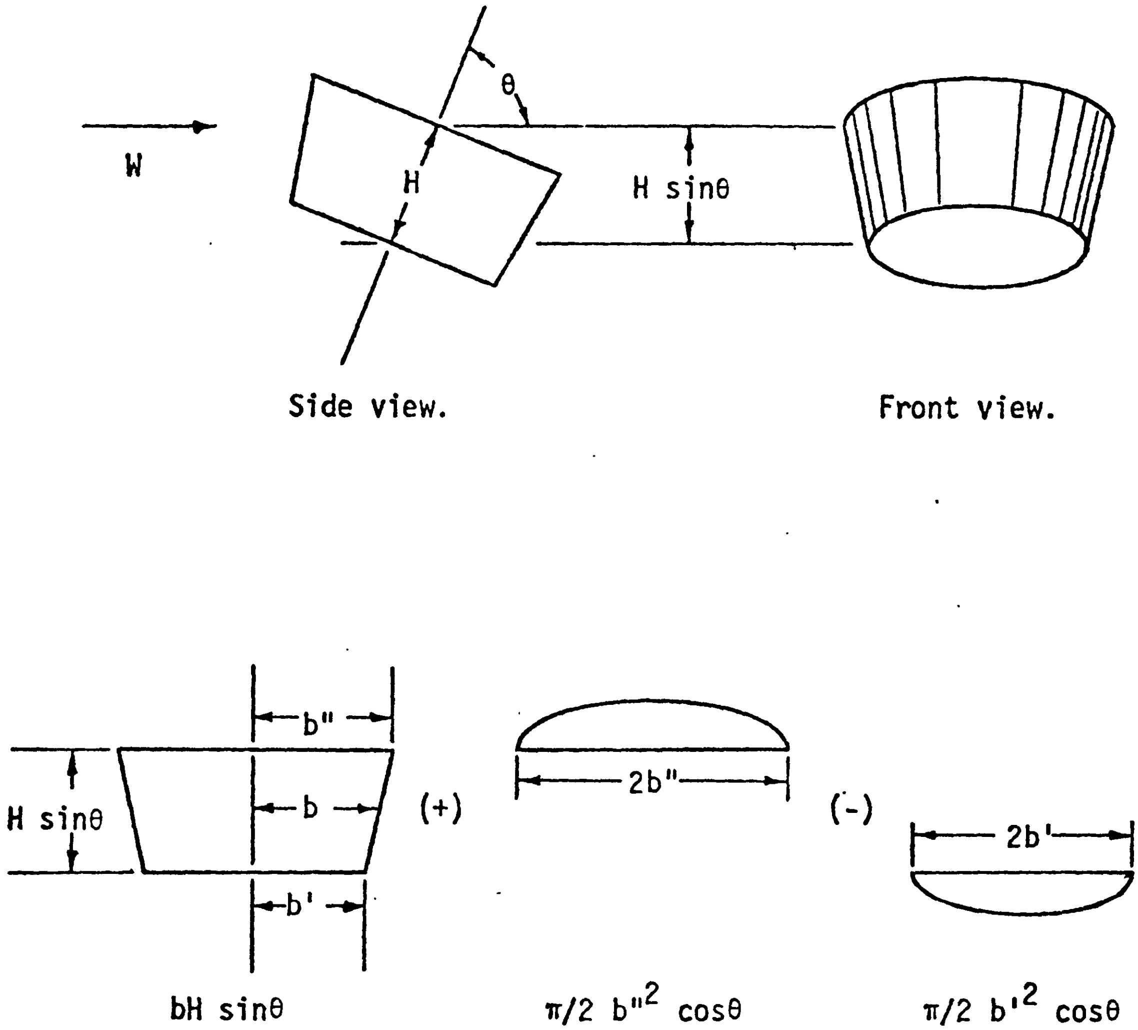
It is imperative to account for these phenomena properly in a detailed quantitative analysis.

Momentum Transfer

The wind can impart horizontal momentum to a plume in two ways:

- by direct entrainment, and
- by pressure differences (drag hypothesis).

It has not been determined how much momentum transfer is due to each mechanism. Hirst [33] maintains that all plume bending is due to entrainment of the wind particles by the plume. This results in essentially the inelastic collision problem exemplified in basic physics. However, according to Winiarsky and Frick, numerical experiments were performed which indicate that the amount of entrainment necessary to achieve observable plume bending by entrainment alone would result in excessive dilution of plume properties. Thus, it is their hypothesis that the transfer of



$$\text{PROJECTED AREA} = 2bH\sin\theta + (\pi/2)(b''^2 - b'^2)\cos\theta$$

$$= 2bH\sin\theta + (\pi/2)(b'' + b')(b'' - b')\cos\theta$$

$$= 2bH\sin\theta + \pi\Delta b\, b\cos\theta$$

FIGURE 3.8

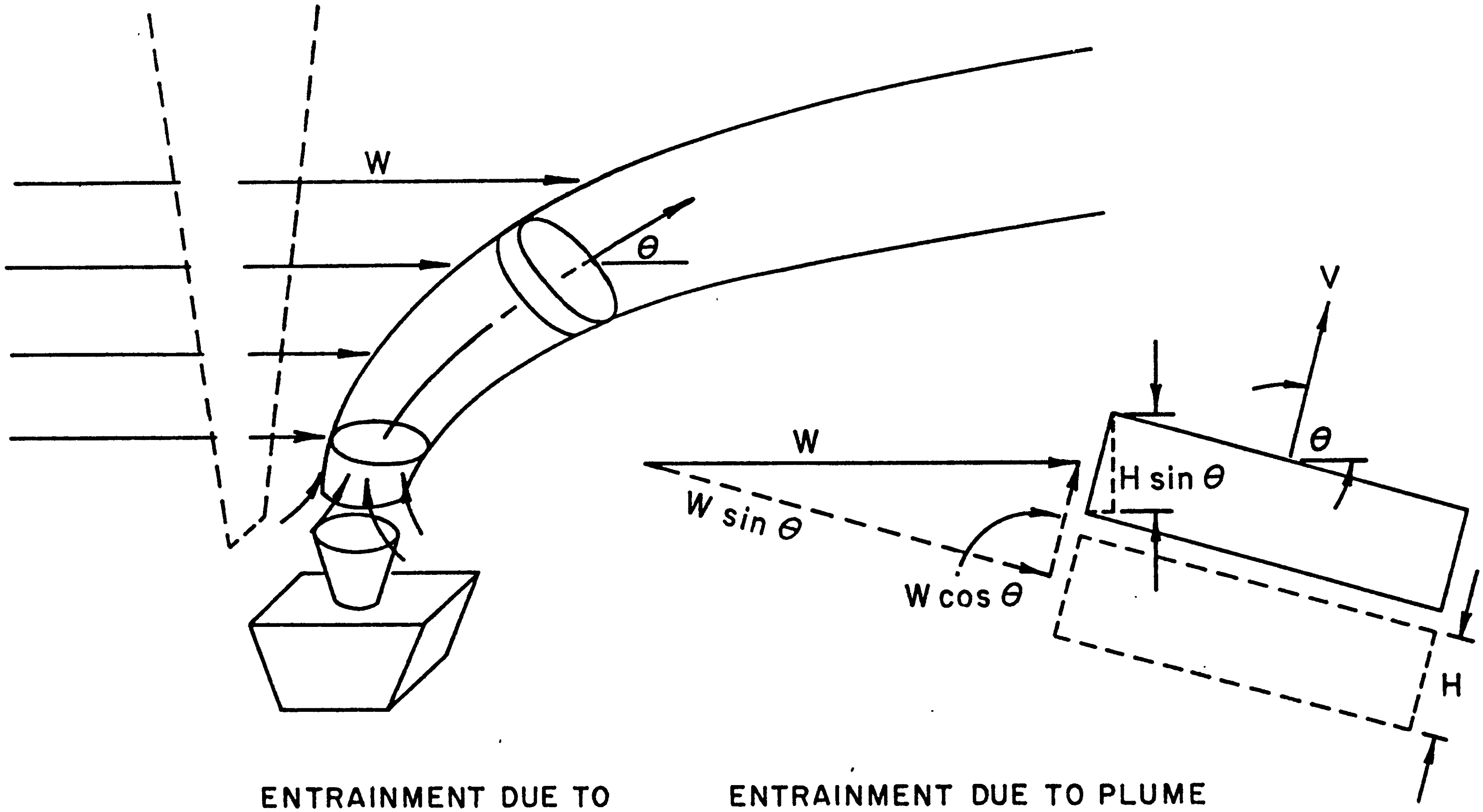
Projected Area of Plume Element (from Winiarsky-Frick,[32]) horizontal momentum from the wind to the plume results primarily from the momentum of the wind that passes around the projected area of the plume (see Fig. 3.8). The mass flowing past this area imparts its momentum to the plume in two ways. Close to the source most of the mass is deflected around the jet. This results in a very strong pressure force. However a short distance from the source, the wind mass begins to penetrate the plume thereby adding momentum by direct entrainment. The plume also induces some mass to be entrained due to the difference between the plume velocity and the wind speed. This is called an aspiration, or shear-type entrainment (see Fig. 3.9). When there is no wind this is the only entrainment mechanism. However this later type of entrainment will be less than the momentum entrained by the wind.

Entrainment

In any detailed calculation of plume behavior, a knowledge of how the plume takes in or mixes with the ambient air is of central importance. However, the various types of mechanisms proposed suggest that that there still exists no consensus regarding the actual nature of the entrainment mechanism of the correct formulation of the jet trajectory.

The volume entrainment is given by:

$$V_{entrain} = w \sin\theta \, 2\pi b \, \Delta s \, \beta$$



ENTRAINMENT = ENTRAINMENT DUE TO WIND IMPINGEMENT + ENTRAINMENT DUE TO PLUME SEGMENT MOVING WITH VELOCITY RELATIVE TO WIND (ASPIRATION)

$$\rho A_{\text{projected}} W \qquad \alpha \rho \pi 2bH|\bar{V} - W\cos\theta|$$

FIGURE 3.9

Entrainment Mechanisms

where $w \sin \theta$ is the component of the wind normal to the plane, b is the radius of the plume element, Δs is the thickness of the plume element, and β is the entrainment coefficient.

In order to find the total entrainment flow, a momentum conservation analysis yields:

$$(\text{entrainment})w = (\rho A p w + \text{aspiration})u$$

where u is the horizontal plume velocity. Henceforth:

$$\text{entrainment} = (\rho A p w + \text{aspiration}) \frac{u}{w}$$

The reasoning used in the model is that if the local horizontal pres pressure force is known or can be estimated, this pressure force can be subtracted from the local horizontal momentum flux to yield the horizontal momentum flux added to the plume by entrainment.

The local horizontal pressure force is approximated as the force required to decelerate the available mass flux to the velocity of the plume:

$$\begin{matrix}\text{Horizontal}\\ \text{pressure}\\ \text{force}\end{matrix} = \left[\begin{matrix}\text{mass flow}\\ \text{through}\\ \text{projected}\\ \text{area}\end{matrix} + \begin{matrix}\text{aspirated}\\ \text{mass}\\ \text{flow}\end{matrix}\right] \times \left[\begin{matrix}\text{wind}\\ \text{velocity}\end{matrix} - \begin{matrix}\text{horizontal}\\ \text{plume}\\ \text{velocity}\end{matrix}\right]$$

Buoyancy

As long as the density of the plume is less than the density of the surrounding air, a net upward force is exerted on the plume parcel. The magnitude of this force can be estimated to be the weight of an equivalent volume of ambient air minus the weight of the plume parcel. This force imparts an acceleration to the plume parcel, but it is not clear how much mass is involved. It appears that when the plume parcel has a vertical motion into the undisturbed atmosphere ambient air must be accelerated due to mixing with the plume.

Moisture

The calculation of moisture effects is sensitive to small density differences. This is particularly noticeable when both the atmosphere and the plume are close to saturation. In this case, the extent of the visible part of the plume is very sensitive to the ambient humidity.

3.5.4 Calculation Procedure

The trajectory of a group of plume particles (a plume puff) is traced in time. The method could basically be classified as a Lagrangian formulation. The plume puff gains mass as ambient fluid is entrained and mixed within it, but once entrained the new mass becomes an indistinguishable part of the plume puff. The initial plume mass is identified as the mass issuing from the tower with radius b_0:

$$M_0 = \rho \pi b_0^2 H_0$$

H_0 is the length of the plume mass and is chosen to be comparable to

b_0 resulting in the relationship

$$H_0 = v_0 \Delta t \quad .$$

The increment in the plume mass is evaluated from the assumed rate of entrainment

$$DM = \sum_i \text{(rate of entrainment)}_i \Delta t \quad .$$

Assuming that the entrainment is a function of the horizontal wind and a shearing action of the plume relative to the wind as mentioned previously one obtains the result

$$DM = \frac{u}{m} \{\rho_{atm}(2bH \sin\theta + \pi b\Delta b \cos\theta) w \Delta t + \alpha 2\pi bH \rho_{atm} \left|\bar{v} - w\cos\theta\right| \} \Delta t \quad ,$$

where Δb is estimated as

$$\Delta b \simeq \frac{\partial b}{\partial s} H \simeq \frac{(b^t - b^{t-\Delta t})H}{\sqrt{\Delta x^2 + \Delta z^2}} \quad .$$

The values of α depend on how the plume width, and characteristic velocity are defined and whether the jet is buoyant. As a first approximation α may be taken to be $\simeq 0.1$ based on experimental studies of submerged jets [31,34].

The new horizontal momentum of the plume is simply the old horizontal momentum plus the horizontal momentum of the entrained mass plus the impulse of horizontal pressure forces on the plume, which can be expressed as

$$u^{t+\Delta t} = \frac{M^t u^t + \Delta M u_w + \text{horizontal pressure force} \cdot \Delta t}{M^t + \Delta M}$$

or

$$u^{t+\Delta t} = \left(M^t u^t + \rho_{atm} (2bH \sin\theta + \pi bdb \cos\theta) w^2 \Delta t + \alpha \rho_{atm} \pi 2bH \,|\, v - w\cos\theta \,|\, w \Delta t\right) / \left(M^t + \Delta M\right) \quad ,$$

and

$$\begin{matrix}\text{horizontal} \\ \text{pressure force}\end{matrix} = \left(\rho_{atm} (2bH \sin\theta + \pi bdb \cos\theta) w + \alpha \rho_{atm} 2\pi bH \,|\, v - w\cos\theta \,|\right) (w - u) \quad .$$

Assuming that the total pressure force vector acts normal to the plume it is possible to approximate a vertical pressure force component as

$$\begin{matrix}\text{vertical} \\ \text{pressure force}\end{matrix} = - \frac{\text{horizontal pressure force}}{\tan\theta} \quad .$$

Similarly, the new vertical velocity due to entrainment is

$$v^{t+\Delta t} = \frac{M^t v^t + (\text{vertical pressure force}) \Delta t}{M^t + \Delta M} \quad ,$$

the new plume mass is

$$M^{t+\Delta t} = M^t + \Delta M \quad ,$$

the new plume temperature is

$$T^{t+\Delta t} = \frac{M^t\, T + \Delta t\, T_{atm}}{M^t + \Delta M} - (\text{ambient lapse})\, \Delta z \quad , \text{ and}$$

the new plume density is evaluated from an equation of state

$$\rho = \frac{p}{RT_v}$$

where T_v is the virtual temperature.

The change in density of the plume relative to the atmosphere results in a buoyant force imparting a vertical acceleration to the plume mass equal to

$$a = \frac{\rho_{atm} - \rho_{plume}}{2\, \rho_{plume}}\, g \quad .$$

This vertical acceleration modifies the new vertical velocity by an amount of

$$\Delta v = a\, \Delta t \quad .$$

Therefore, one obtains the result

$$v^{t+\Delta t} = v^{t+\Delta t} + \Delta v \quad .$$

The new location (trajectory of the plume puff) is

$$x^{t+\Delta t} = x^t + \frac{u^t + u^{t+\Delta t}}{2}\, \Delta t \quad , \text{ or}$$

$$z^{t+\Delta t} = z^t + \frac{v^t + v^{t+\Delta t}}{2}\, \Delta t \quad .$$

The speed of the plume puff along the trajectory is obtained as

$$\bar{v} = \sqrt{u^2 + v^2} \quad , \text{ and}$$

the angle of indination is given as

$$\sin\theta = \frac{\bar{v}}{\sqrt{u^2 + v^2}} \quad .$$

The average radius of the plume puff can be found to be

$$M = \rho \pi b^2 H \quad ,$$

where:

$$H^{t+\Delta t} = H^t + \frac{(\bar{v}^t - \bar{v}^{t-\Delta t}) H^t \, \Delta t}{\sqrt{\Delta x^2 + \Delta z^2}} \quad .$$

3.5.5 Moisture Computation

For superheated conditions moisture is treated as a simple conservative property described as

$$Q_2 = \frac{Q_1 M + Q_a \Delta M}{M + \Delta M} \quad .$$

The saturation mixing ratio is given by the integrated Claudius-Clapeyron equation

$$q_s = \frac{(6.11)(.622)}{1000} \exp\left[\frac{L}{R_w} \frac{(T_2 - 273)}{273\, T_2}\right] \quad ,$$

where R_w = perfect gas constant for water vapor.

And the temperature rise Δt caused by condensation can be approximated by

$$\Delta t = \left[\frac{T_1 - T_a}{q_1 - q_a} - 0.622 \frac{R}{Lq_1} \frac{T_1^2}{q_1 + 0.622}\right](q_1 - q_2) \quad ,$$

where q_1 = the initial mixing ratio,

q_2 = the final mixing ratio for dry mixing,

q_q = the ambient mixing ratio,

T_1 = the initial temperature,

T_2 = the final mixing ratio for dry mixing, and

T_a = ambient temperature.

The change in liquid water vapor is then seen to be

$$\Delta\sigma = \frac{c_p \Delta t}{L} \quad , \text{ and}$$

the adjusted amount of liquid water mixing ratio becomes

$$\sigma = \frac{\sigma_m + \sigma_a DM}{M + DM} + \Delta\sigma \quad .$$

If (T_2, Q_2) falls below the saturation line, evaporation begins. This mechanism is handled in the same way as the condensation mechanism.

3.5.6 Connection Between the Integral Entrainment Model and the Turbulent Buoyant Plume

The Winiarsky and Frick model [32] has been modified to yield an output of variables compatible with the input required by the turbulent buoyant plume model (see Table 3.3). A correlation the buoyancy length has been implemented in the entrainment model in order to integrate the problems on a scale comparable to the buoyancy length. Given that the Winiarsky and Frick model is compatible with the basic conservation laws the input variables of the turbulent plume model will also be compatible with those laws provided that the data available are accepted by the same standards. (The approach is universal and can be used to study any field case provided that the plume length is bigger than the buoyancy length.) As the plume entrains air its radius becomes larger. By choosing the appropriate mesh increments one can generate the plume cells that must be initialized in the numerical model and their corresponding thermodynamic and hydrodynamic quantities. Respectively one reads (Table 3.3), the coordinates of the cell, then on the next line the specific internal energy (SIEI), the turbulent kinetic energy (TQE), the turbulent kinematic viscosity (TNU) (these two variables are not generated by the model), the "x" velocity (UI), the "z" velocity (WI), the pollutant concentration (CHII), the vapor density (VAPI), the liquid density (LIQI).

Type of Boundary Condition

NT

NB

NR

NL

```
  2      2     10    23  1
89.376  0.000  0.000    0.0      2.232    0.0   0.0011550.0
  3      3     11    22  1
89.376  0.000  0.000    0.0      2.232    0.0   0.0011550.0
  4      4     12    21  1
89.376  0.000  0.000    0.0      2.232    0.0   0.0011550.0
  5      5     13    20  1
89.376  0.000  0.000    0.0      2.232    0.0   0.0011550.0
  6      6     14    19  1
89.376  0.000  0.000    0.0      2.232    0.0   0.0011550.0
  7      7     15    18  1
89.376  0.000  0.000    0.0      2.232    0.0   0.0011550.0
  8      8     16    17  1
89.376  0.000  0.000    0.0      2.232    0.0   0.0011550.0
```

SIE1 Specific Internal Energy

LIQI Liquid Density

VAPI Vapor Density

CHII Pollutant Concentration

VI (oz)Velocity

UI (ox)Velocity

TNU Turbulent Viscosity

TKE Turbulent Kinetic Energy

Table 3.3.

Output from the Entrainment Model

3.5.6.1 Conclusion

A study performed at Argonne National Laboratory has [35] assessed this model's performance. In the group of the four best models its rise predictions are the best, and its length predictions, while usually short, place the model among the best three for visible plume length predictions. Winiarsky and Frick have calibrated the model to a larger data base than have other modelers. This base includes single-phase data and some of the Lünen and Chalk Point cooling tower data. However, the calibration has not been done by selection of values for adjustable constants, but by varying the model's physical assumptions. The manner of doing this is illustrated by the choice to use entrainment by impingement or aspiration but not both. The choice of the Winiarsky and Frick model is justified by both its simplicity and performance. The model has been tested against available data for the Chalk Point June 23rd plume, where it is seen that the quality of the results is good (see Fig. 3.10).

3.5.7 Atmospheric Profiles of Wind, Temperature, and Humidity

3.5.7.1 Introduction

The data base used to validate the turbulence model was acquired by the Kansas 1968 Field program. A micrometeorological experiment conducted during the summer months by the Boundary Layer Branch, Meteorology Laboratory, Air Force Cambridge Research Laboratories (now the Air Force Geophysics Laboratories). The principal object of the experiment was to make direct measurements of vertical profiles of wind and temperature in the atmospheric layer over a horizontally uniform terrain. The turbulence correlations obtained in this work were tested against the experimental measurements obtained in the program.

The data for the validation of the plume model has been provided by the Tennessee Valley Authority. The measurements were performed at the Paradise Steam Plant, a coal-fired power plant with three hyperbolic natural-draft, wet, counterflow cooling towers. The data were intended to verify various models for vapor plume that are now used in cooling-tower plume models. The Paradise measurements offer a spectrum of plumes that are difficult to reproduce with currently-used models. It therefore represents a good test to the numerical plume model addressed in this work.

3.5.8.2 Experimental Site and Procedure

The vertical atmospheric profiles considered in this paragraph are ideally supposed to be measured with the appropriate meteorological instruments over flat terrains [36]. In the case of the turbulence model, the focal point of the micrometeorological site was a 32 meter instrument tower in the center of the square mile section. The entire section was dry and covered with wheat stubble about 18 cm high. The upwind fetch for the 32 m tower was 2400 m of horizontally uniform, flat terrain.

The length of the observation period for individual runs was limited to one hour, and the basic averaging period for the collected data used was 15 min. Thus, there is very little time-dependence in the profile. The instrumentation for the field program consisted of the following:

1) fast-response instruments for direct measurements of heat and momentum fluxes, and

2) slow-response instruments for measurements of vertical profiles of wind speed and temperature.

The cup anemometers were mounted at heights of 2, 4, 5.66, 8, 11.31, 16, 22.63, and 32 m on the tower. All cup anemometers were calibrated in a low-speed wind tunnel before and after the field measurements.

Temperature and temperature differences were measured with a slow-response system using shielded and aspirated platinum resistance thermometers. The system was claimed by the experimenters to yield mean values of temperature and temperature differences with resolution of 0.05 C and 0.01 C, respectively. Sensors to measure temperatures were mounted at 2 and 22.63 m and those to measure temperature differences at 2, 4, 8, 16, 22.63 and 32 m.

In the case of the Paradise field case, wind profiles and source operational data were obtained for the time periods during which plumes were photographed.

The dry-bulb and dew point temperature profiles of ambient air were obtained from an instrumented Bell Model 47J2 helicopter. A fast response micro-bead thermistor and bridge circuit were used to measure ambient dry-bulb temperatures, and a Cambridge model 137-C3 aircraft hygrometer was used to measure the ambient dew-point temperature. The helicopter elevation was recorded from a calibrated altimeter on the helicopter.

The wind speed and direction profiles were obtained using balloons. Pilot balloons were released continuously during the period when the plume was being photographed.

The ambient dew-point temperature profiles were also acquired from an instrumented helicopter.

Given these measurements one has directly the temperature and velocity profiles and from the dew-point profile one can indirectly (using the psychrometric chart) obtain the relative humidity profile. The temperature and humidity profiles directly provide the information about the local stability of vertical atmospheric and plume motion. They are also used to compute the virtual potential temperature profile.

3.5.9 Pressure Profile

The pressure profile is required at any height. The pressure profile should be measured by itself or calculated using a number of

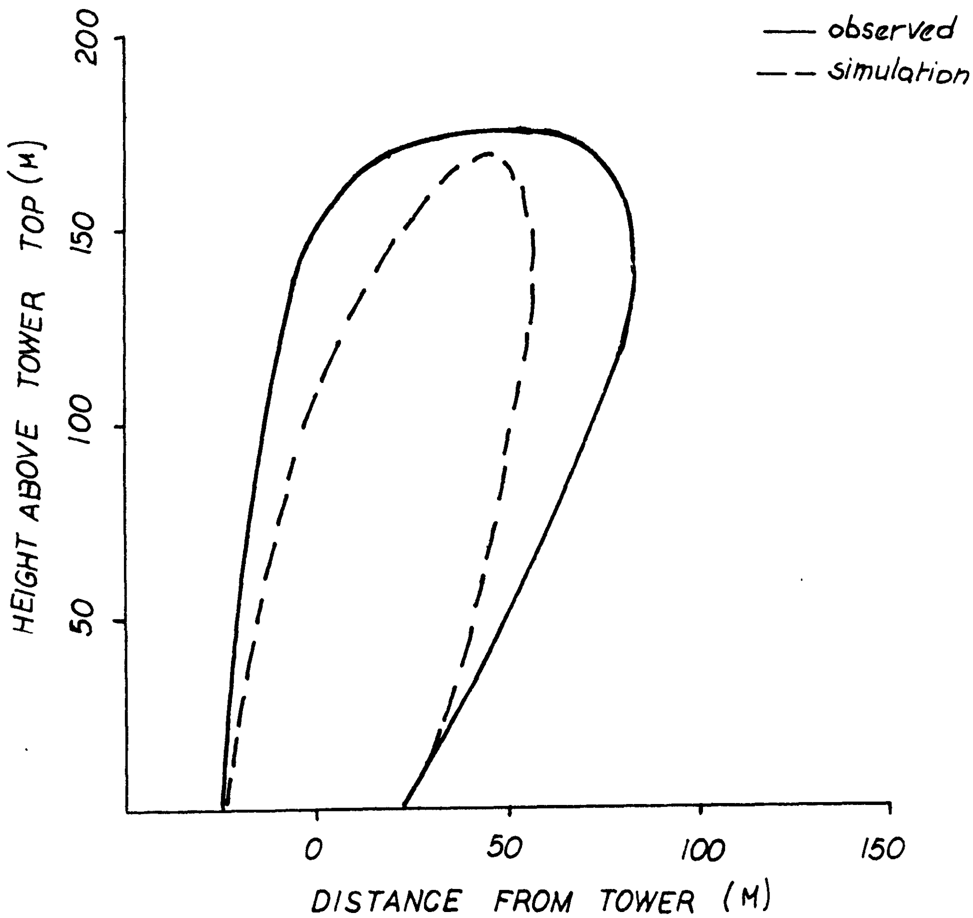


FIGURE 10
Comparison Between the Experimental Results and the Entrainment Model Simulation of the June 23rd Chalk Point Cooling Tower Plume
CPJ-23

approximations (dry hydrostatic, moist hydrostatic, etc.). The pressure profile consistent with these assumptions must be used as input to the simulation where it is used to recalculate the correct temperature from the virtual potential temperature and humidity for the equilibrium moisture thermodynamics model.

3.5.10 The Liquid Water Profile

One important consideration that is seldom given the appropriate attention is the amount of liquid water that is rejected by cooling towers. Recent measurements by Dibelius and Ederhof [37] show that most of the emitted liquid water (90%) is in the form of recondensate water and only 10% of the liquid water is drift (see Fig. 3.11). Figure 3.5.10.7 shows the flux of liquid water as a function of the droplet size. There are two distributions shown, the first centered around 50 μm, and the second centered around 4 μm. The origin of these two distributions is demonstrated by the second curve (dashed lines) which corresponds to a zero power load (i.e., no heat rejection). As can be seen, the smaller droplet size distribution is now flat while the larger size distribution remains unchanged. We can easily deduce that the contribution by the larger droplets is due to the drift while the smaller droplet contribution is due to the recondensate water.

The liquid recondensate water of a cooling tower is seldom measured, even in test field studies, and is certainly not available

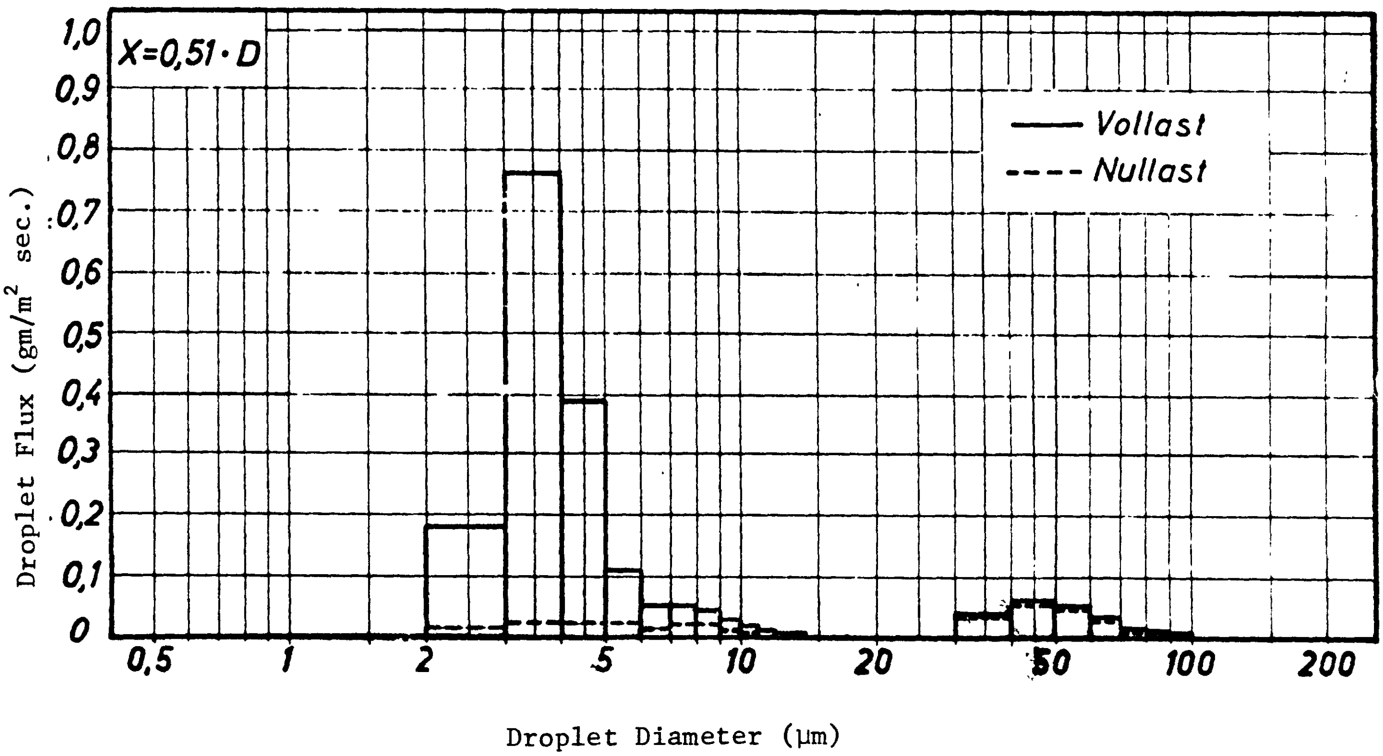


Figure 3.11

The Water Droplet Flux As A Function of the Droplet Diameter
At the Tower Exit

for environmental impact analysis except as a design value. However, given the effects of the liquid water content of a plume on both the plume rise and the plume length we found it important to have a systematic approach to the initialization of the liquid water content of a plume.

3.5.10.1 Sensitivity

Cooling tower plume-air exiting from tower top is normally assumed to be 90 to 100% saturated. Models which assume a default value of the initial plume relative humidity which is less than 100% assume that an averaging of moisture conditions in the tower exit plane occurs, which includes saturated areas of air as well as unsaturated areas due to turbulence and vortex action, leads to an averaging mixing ratio below saturation. Actually the plume-air is generally taken to be saturated as it leaves the cooling tower, carrying with it some excess liquid water. The Winiarsky and Frick model assumes a default value of 0.001 kg of water per kg of air as the amount of liquid water present in the plume of the tower exit. This value is typical of the liquid water content found in natural cumulus clouds.

Sensitivity studies using several numerical plume models have been carried out [31]. The studies show that increasing the initial liquid water content increases the visible length and rise. Increased liquid water directly adds to the life of the visible portion of the plume and thereby increases its length. The trajectory of the plume is lowered slightly due to the fact that increased liquid water adds weight to the plume parcels. However, the net plume rise is increased by the more dominant, lengthening effect. In contrast, decreased liquid water emissions causes shortening of the plume length and lowered visible rise. The percentages of increase or decrease are dramatically dependent on the ambient weather conditions. For winter cases the visible plume rise and length are shortened by few percent (5-10%). For summer cases the plume rise and length can vary from 30% to as much as 80% [37]. Consequently it is seen that accurate and systematic liquid water initialization is required in order to model properly visible plumes.

3.5.10.3 Initial Liquid Water Content

Dibelius and Ederhof [38] have made numercous measurements with their diffuse light probe at NDCT, MDCT and experimental towers. They have found an empirical correlation between the re-condensate liquid water emission and tower ambient parameters. A mathematical formula was developed at Argonne National Laboratory to represent the empirical data [35]. The same correlation is applied for both NDCT and MDCT prototype applications. Recent measurements at the NDCT at Meppen in the Federal Republic of Germany indicated additional verification of this correlation.

The correlation provides that the more efficient a tower is on a particular date in dissipating the waste heat, the less recondensate liquid is emitted by the tower.

According to the relationship

$$\frac{\dot{m}_r}{m_{Ltr}} \cdot 10^3 = \frac{2.39}{(1.0 - 7.95\,\chi)^2} \text{ , where}$$

$$\chi = \frac{T_{KWE} - T_{KWA}}{T_{KWE} - T_{UT}} \text{ , and}$$

$\dfrac{\dot{m}_r}{m_{Ltr}}$ = liquid water emission in g water/g air,

T_{KWE} = hot water temperature,

T_{KWA} = cold water temperature, and

T_{UT} = ambient dew point temperature.

4 DESCRIPTION OF THE PLANETARY BOUNDARY LAYER

Introduction

The basic energy source that feeds the whole atmosphere machine is solar short wave radiation. Part of this energy is directly scattered or reflected back to space. The residue is transformed into heat, only a small part of which is absorbed by the air and the clouds: the atmosphere is essentially heated from below. At this stage, turbulent transfer is one of the controlling factors of the atmospheric temperature distribution. Reflection scattering and absorption of solar radiation in the atmosphere is strongly dependent upon the distribution of clouds (governed itself by the distribution of water vapor and condensation nuclei), aerosols, and various physical-chemical components.

The next physical mechanism that enters the picture is long-wave or infrared, radiation which is emitted and absorbed by the surface of the land or of the sea, the clouds or the atmosphere itself. In the atmosphere, complicated processes occur, the consequences of which cannot be ignored. Even clear air is not totally transparent to long wave radiation mainly because of the presence of water vapor and carbon dioxide, and is therefore able partially to absorb the incoming radiation, as well as to reradiate energy. This results in a mechanism called "infrared radiative transfer" by which energy is transfered from

from place to place at a rate which depends, in a complicated way, on the distributions within a vast volume of such variagles, specific mass, and concentrations in H_2O and CO_2. At this level, also, turbulence appears as an indirect controlling agent.

Apart from radiative processes, water vapor transfer is by far the most important mechanism for the energetics of the atmosphere. On the average water vapor contributes approximately eighty percent of the atmosphere fuel [35] because of the high latent heat of vaporization of water.

From what has been said it can be seen that the distribution of temperature will be uniform neither in space nor in time within the atmosphere system. Taking into account the equation of state, and the effects of gravity, one can see that this leads to uneven repartitions of density and pressure. This is the source of nearly all atmospheric motions. Some of them are directly generated at small or medium scales: this is the case for convective updrafts in the absence of wind near a heated ground. Others are initiated as large-scale motions, starting with the general circulation itslef, the mean field source of turbulence which gives rise to large-scale eddies, and all of them are strongly influenced by turbulence which is the reason for the friction forces that finally put an end to all kinds of atmospheric motions.

The region of the atmosphere where the effect of turbulent shear stresses is the more evident is the so-called "Planetary Boundary Layer" or "P.B.L." that occurs quasi-permanently in the 500-1500 lowest meters. The turbulent downward transfer of kinetic energy that takes place within the P.B.L. is responsible for the slowing down of large-scale motions. But all of the kinetic energy which is generated in the air or water masses has to be finally dissipated into heat. The role of turbulence is essentially here: it is through eddy diffusion that the energy initially generated at relatively large scales can be transferred to structures of sufficiently small scales, so that the viscous dissipation can act as a sink.

4.1 Specific Properties of Atmospheric Turbulence

The study of turbulence involves many physical phenomena. Its understanding depends upon the knowledge accumulated in many other fields. In addition the important turbulent and thermal characteristics of the atmosphere cannot be simulated in the labo laboratory. Thus, direct measurements in the atmosphere are the sole source of experimental analysis.

4.1.1 Large Dimension of the Flow

The characteristic length and velocity scales associated with atmospherical flows are such that extremely large Reynolds numbers are attained. The length scales at which the production of turbulent energy takes place are, thus, typically several orders of magnitude larger than those scales at which it is dissipated.

4.1.2 Buoyancy Effects in General

We wish to look at the problem at smaller scales and to examine the direct influence of gravitational forces upon the level and structure of turbulent motions themselves. Atmospheric turbulence is often characterized by relatively small velocity differences and large density differences: in such situations, one can expect that turbulence will be strongly affected by gravitational forces.

In the case where the density decreases rapidly with altitude increases one encounters a "stable stratification," such as in atmospheric inversions. Any fluid particle that moves vertically is then subject to a buoyant force that tends to bring it back to its original elevation. Turbulent structures must permanently work against gravitational forces, and they lose their kinetic energy at the profit of the gravitational potential energy of the medium. This can lead in extreme cases, to a complete relaminarization of the flow.

In the inverse wise when density increases with altitude, we have an "unstable stratification." Body forces tend to remove farther any fluid particle that has left its initial elevation: these forces work to increase the kinetic energy of turbulence at the expense of the mean potential energy. In the extreme situation known as "free convection" this leads to a state of turbulence that is entirely driven by gravity.

The relative influence of buoyancy upon the structure of turbulence can best be characterized by the ratio of the rate at which turbulent kinetic energy is produced (or destroyed) at the expense (or profit) of the gravitational potential energy through the work of body forces.

4.1.3 Water Vapor, and Phase Changes

Turbulence of water vapor concentration is generally associated with dynamic turbulence in the atmosphere. Like temperature, specific humidity is an active contaminant that contributes substantially to the density changes which are important in atmospheric turbulence.

A still open question is whether the behavior of temperature turbulence and moisture turbulence are strictly similar. In this connection changes of phase are very important. They act in various ways because of the following effects:

- The sensible heat source or sink associated with condensation, evaporation, freezing, sublimation, that has repercussions on the temperature field structure;
- the changes in density, and thermodynamical behavior which are associated with changes of phase, and which affect the convectional stability of air masses, and

- the largely different behavior of unsaturated air and saturated air with respect to radiative transfer of energy.

4.1.4 Effects of the Earth's Rotation

Coriolis acceleration is known to be one of the most important factors for atmospheric motions: in the absence of friction, it is responsible for the apostrophic winds, while in conjunction with turbulent shear stresses it gives rise to the various kinds of "Ekman layers." The average structure of atmospheric turbulent flows is quite generally influenced by the earth's rotation, the most obvious effect being that the mean velocity field is usually characterized by a change in direction with height. In contrast, most laboratory flows are of the "quasi-parallel" type, and do not reflect coriolis effects.

The question, however, is to know whether or not coriolis acceleration has an influence upon the structure of turbulence itself. To answer this question, one must estimate the relative importance of inertial and coriolis accelerations at a given scale of motion.

If we consider the horizontal frictionless motion of a fluid particle, with initial velocity u_0, at latitude ψ. The vertical components of the earth's rotation vector are then $\Omega \sin \psi$, so the equations of motions are the following:

$$\frac{du}{dt} = 0, \text{ therefore } u = \text{constant} = u_0$$

$$\frac{u_0^2}{R} = 2\,\Omega \sin\psi\, u_0 = f\, u_0 \tag{4.1}$$

where $f = 2\,\Omega \sin\psi$ is known as the coriolis parameter, and R is the distance to the axis of rotation. Therefore we obtain the result

$$R = \frac{u_0}{2\,\Omega \sin\psi} = \frac{u_0}{f} = \text{cte}$$

This trajectory is a circle (the circle of inertia) which the particle travels at constant peripheral velocity u_0, in a time-independent period,

$$T_P = \frac{2\pi R}{u_0} = \frac{2\pi}{2\,\Omega \sin\psi} = \frac{2\pi}{f} \quad , \tag{4.2}$$

where T_P is called the "inertia period." For a latitude near 45°, it is approximately equal to 18 hours.

Consider now a harmonic motion, of characteristic velocity u_0 and period T. The ratio of inertia to coriolis accelerations will then be:

$$R_0 = \frac{2\pi u_0/T}{2\,\Omega \sin\psi\, u_0} = \frac{2\pi u_0/T}{f u_0} = \frac{T_P}{T} \quad , \tag{4.3}$$

where R_0 is known as the Rossby number.

We thus see that, at middle latitudes, earth's rotation will be of primary importance for atmospheric motions of periods of order longer than 18 hours, and of little importance for motions of much smaller periods. The flows modelled in this work are in the latter class.

4.2 The Process Leading to the Generation or Destruction of Turbulence

In an unstratified atmosphere, the level of turbulence is controlled by the balance between the production mechanism which feeds energy from the mean flow kinetic energy, and the dissipation mechanism which carries turbulent energy through the inertial cascade down to small scale viscous dissipation. These two processes subsist but, as soon as the momentum flux Richardson number leaves the zero value characteristic of neutral stability, the gravitational mechanism acts as an additional source or sink of turbulent energy. When the stratification is stable (i.e. $R_f > 0$), it is a sink: as soon as R_f is larger than approximately 0.1, turbulence begins to lose energy at the profit of potential energy of the fluid. As noted by Richardson, it will no longer be able to sustain itself when that loss will be of the same order as the mechanical production. In other words, we can expect a "gravitational detransition" (noted L.2) for $R_f \sim 1$. On the other hand, when stratification is unstable ($R_f \sim 0$). The gravitation mechanism is an additional source of turbulent energy. It leads, when the absolute value of R_f increases from 0.01 to 5, to a progressive transition (noted T4) from the "forced convection" regime, to the "mixed convection" regime, and then to the "free convection" regime characterized by a total preponderance of vertical buoyancy induced turbulent motion.

4.2.1 Conditions Necessary for the Initial Appearance of Turbulence

- The usual "mechanical" transition is associated with the mechanical instability of a neutral buoyant mean flow (T1). It will occur in free flow when the velocity profile has an inflexion point, and near the wall when the the Reynolds number is larger than a critical value (of order 400).
- The "convective" transition (T2) corresponding to a gravitationally-driven instability. Such an instability initially leads to well-organized convection cells, then, with increasing Rayleigh number, to more and more complex motions of turbulent character. The lower critical limit corresponds to a Rayleigh number of order 700, and therefore can be expressed as a function of the Reynolds number, and the gradient Richardson number

$$Ra = \frac{g\,\Delta\rho\,L^3}{\nu\lambda} \quad , \tag{4.4}$$

where $\nu = \frac{\mu}{\rho}$, and $\lambda = \frac{\rho k}{c_p}$, where k is the thermal conductivity,

c_p the heat capacity at constant pressure, and

ν the kinematic viscosity.

We can rewrite the Richardson number as:

$$Ra = \frac{g\,\Delta\rho\,L^3}{\nu\lambda} = \frac{g\,\Delta\rho\,L}{\Delta u^2}\left(\frac{L\Delta u}{\nu}\right)^2\frac{\nu}{\lambda} = Ri\,Re^2\,Pr \tag{4.5}$$

- The third type of transition, called "Kelvin Helmholtz instability" (T3) is encountered in stably stratified situations. It occurs when the destabilizing influence of the wind shear overcomes the stabilizing effect of the density gradient. A necessary condition is that the gradient Richardson number be locally below a critical figure of 0.25. It is considered as being the main source of turbulence in the free atmosphere [3].

Figure 4.1 is a schematic representation of all processes leading to the generation or destruction of turbulence. It can be seen that the presence of turbulence is largely governed by the local values of both the Reynolds and the Richardson numbers.

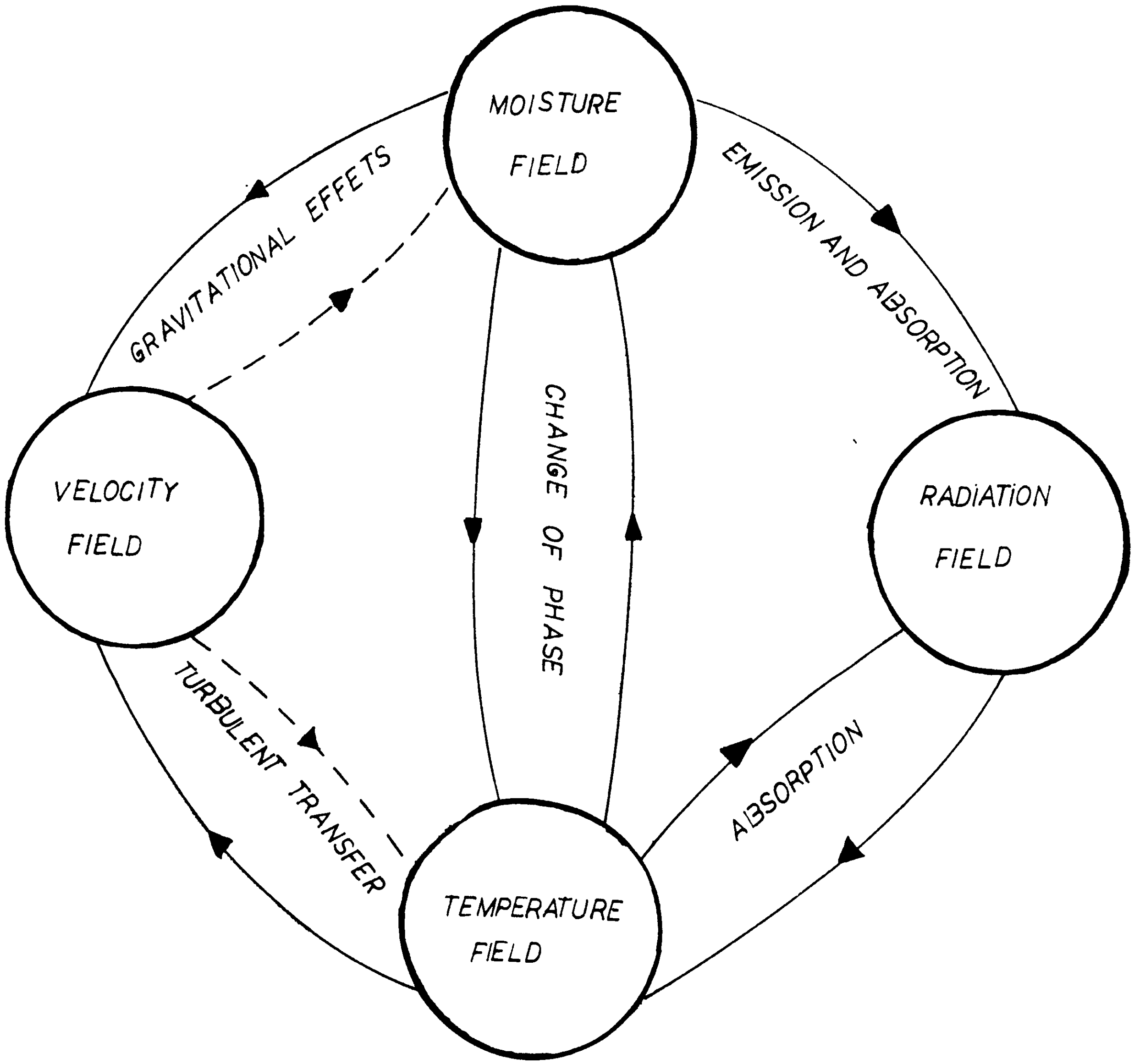


FIGURE 4.1

Schematic Picture of Interaction Between
Turbulent and Radioative Processes in the Atmosphere

4.3 Goal, Assumptions, and Simplified Equations

4.3.1 Introduction

The need to prescribe turbulent parameters in the buoyant plume model requires the development of a planetary boundary layer model. The complexity of the physical phenomena involved in such modeling makes the cost of a detailed three-dimensional model prohibitively great. Yet the goal of this work is to build a model for engineering applications. Therefore we have confined our efforts to building a planetary boundary layer model that can be integrated into the plume model. It is required that this model be relatively simple and not prohibitively expensive. Nevertheless the complexity of the physical phenomena involved in turbulence modeling is such that even "simple" models require a reasonably complex mathematical treatment. In this paragraph, we shall begin by studying the properties of some of the most elementary solutions which one can obtain from the simplified set of equations established in Chapter 3. From this we shall define the type of model that we are seeking and the different parameters that we shall model.

4.3.2 Horizontal Homogeneity and its Implications

The set of equations governing the basic hydrodynamic and thermodynamic variables are the following [39]:

Continuity Equation

$$\frac{\partial \bar{u}_i}{\partial x_j} = 0 \quad , \tag{4.6}$$

Momentum Equation

$$\frac{\partial \bar{u}_i}{\partial t} + \bar{u}_j \frac{\partial \bar{u}_i}{\partial x_j} = - \frac{1}{\rho_0} \frac{\partial \bar{p}}{\partial x_i} + \frac{\rho - \rho_0}{\rho_0} g_i \delta_{i3} + \nu \frac{\partial^2 \bar{u}_i}{\partial x_j^2}$$

$$- \frac{\partial}{\partial x_j} (\overline{u_i u_j}) - 2 \varepsilon_{ijk} \Omega_j \bar{u}_k \quad \text{, and} \tag{4.7}$$

Energy Equation

$$\frac{\partial \bar{\theta}}{\partial t} + \bar{u}_j \frac{\partial \bar{\theta}}{\partial x_j} = \nu \, Pr^{-1} \frac{\partial^2 \bar{\theta}}{\partial x_j^2} - \frac{\partial}{\partial x_j} (\overline{u_j' \theta'}) \tag{4.8}$$

We shall restrict ourselves to problems encompassing a sufficiently small horizontal extent, so that the earth's curvature and the change in latitude of the local components of earth's components of earth's rotation can be ignored. Now the simplest situation we can consider is that of the case where all boundary conditions that influence the behavior of the solutions of the system are uniform horizontally. This will be the case when looking at the lower atmosphere above a flat horizontal terrain of uniform properties.

The changes in the horizontal directions of all variables are assumed to be small compared to the changes in the vertical direction (except for the pressure). This implies that horizontal changes are occurring over such large scales that the corresponding derivatives $\frac{\partial}{\partial x_1}$, $\frac{\partial}{\partial x_2}$ can be entirely ignored with respect to the vertical partial derivative $\frac{\partial}{\partial x_3}$. Therefore all variables (except pressure) will be considered to be functions only of the vertical coordinate $x_3 \equiv z$.

One immediate consequence of this assumption is that the average atmospheric motion is confined to horizontal planes. This is shown from the continuity equation

$$\frac{\partial \bar{u}_3}{\partial x_3} = - \left(\frac{\partial \bar{u}_2}{\partial x_2} + \frac{\partial \bar{u}_1}{\partial x_1}\right) = 0 \tag{4.9}$$

by taking into account the fact that $\bar{u}_3(0) = 0$, with the consequence that

$$\bar{u}_3(x_3) = cte = 0 \tag{4.10}$$

The momentum equation for the vertical direction is then:

$$0 = - \frac{1}{\rho_0} \frac{\partial \bar{p}}{\partial x_3} + \left(\frac{\rho - \rho_0}{\rho_0}\right) g - \frac{\partial}{\partial x_3} \overline{u_3'^2} \tag{4.11}$$

which can be integrated as:

$$\bar{p}(x_3) = \bar{p}(0) - \overline{\rho_0 u_3'^2} + \int_0^{x_3} (\rho - \rho_0)\, g\, dx_3 \quad . \tag{4.12}$$

The pressure distribution in the vertical direction is thus hydrostatic, except for a negligible correction corresponding to the vertical Reynolds stress. Taking the derivative with respect to x_1 and x_2 of equation (4.12) we also obtain the results

$$\frac{\partial\bar{p}}{\partial x_2}(x_3) = \frac{\partial\bar{p}}{\partial x_2}(0) \quad ,$$

$$\frac{\partial\bar{p}}{\partial x_1}(x_3) = \frac{\partial\bar{p}}{\partial x_1}(0) \quad . \tag{4.13}$$

Thus, we can disregard entirely the vertical momentum equation, and take $\frac{\partial\bar{p}}{\partial x_2}$ and $\frac{\partial p}{\partial x_2}$ as being constant given by external synoptic conditions.

Assuming homogeneous flow E_q (4.7) yield the forms

$$\frac{\partial\bar{u}}{\partial t} = -\frac{1}{\rho_0}\frac{\partial\bar{p}}{\partial x} + f\bar{v} + \frac{\partial}{\partial z}\left(\nu\frac{\partial\bar{u}}{\partial z} - \overline{uw}\right) \quad \text{, and} \tag{4.14}$$

$$\frac{\partial\bar{v}}{\partial t} = -\frac{1}{\rho_0}\frac{\partial\bar{p}}{\partial y} - f\bar{u} + \frac{\partial}{\partial z}\left(\nu\frac{\partial\bar{v}}{\partial z} - \overline{vw}\right) \quad , \tag{4.15}$$

Equation (3.8) yields the result

$$\frac{\partial\bar{\theta}}{\partial t} = \frac{\partial}{\partial z}\left(\nu\,Pr^{-1}\frac{\partial\bar{\theta}}{\partial z} - \overline{w\theta}\right) \quad , \tag{4.16}$$

where $f = 2\,\Omega_z = 2\,\Omega\sin\psi$.

4.3.2.1 The Geostrophic Wind

In places where the friction terms on the right hand side of equations (4.14) - (4.16) can be neglected (e.g. this is the case at the top of the P.B.L.), these equations take the forms

$$f\bar{v} - \frac{1}{\rho_0}\frac{\partial\bar{p}}{\partial x} = 0 \quad \text{, and}$$

$$f\bar{u} + \frac{1}{\rho_0}\frac{\partial\bar{p}}{\partial y} = 0 \quad . \tag{4.17}$$

They give the well-known expressions for the "geostrophic wind":

$$u_G = \frac{1}{\rho f}\frac{\partial\bar{p}}{\partial y} \qquad \text{and} \qquad v_G = \frac{1}{\rho_0 f}\frac{\partial\bar{p}}{\partial x} \tag{4.18}$$

which express the Buys-Ballot law (3 bis): the geostrophic wind, $\underline{G}$, is tangent to isobars. Its absolute value is directly proportional to the horizontal pressure gradient:

$$|G| = \frac{1}{\rho_0 f}\,|\bar{\nabla}_{hor}\bar{p}| \tag{4.19}$$

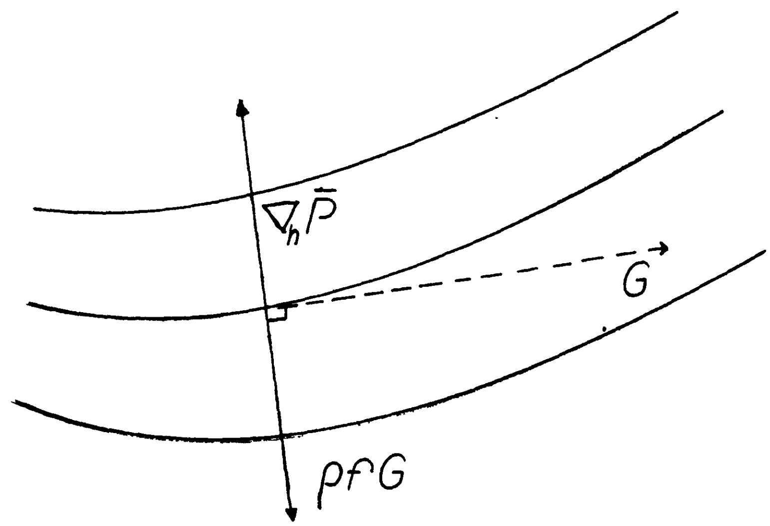
The situation is illustrated in Fig (4.2).

4.3.3 Transient States, and the Assumption of Stationarity

Given the temperature and the velocity fields (from measurements) one seeks the Reynolds stress fields. The reliability of the results depends upon the sophistication of the model addressed. In order of increasing complexity we shall present some basic approaches to this problem.

The simplest method is to assume a constant effective viscosity in each medium so that:

$$\nu\frac{\partial\bar{u}}{\partial z} - \overline{uw} = \nu_T\frac{\partial\bar{u}}{\partial z}$$



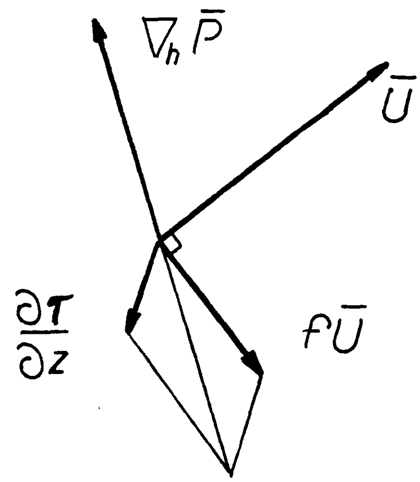


FIGURE 4.2

The Balance of Forces in the Steady State Situation

$$\nu \frac{\partial \bar{v}}{\partial z} - \overline{vw} = \nu_T \frac{\partial \bar{v}}{\partial z} \tag{4.20}$$

Combining Eqs. (4.20), (4.14) and (4.15), we have the expressions

$$\begin{aligned} \frac{\partial \bar{u}}{\partial t} &= f(\bar{v} - v_G) + \nu_T \frac{\partial^2 \bar{u}}{\partial z^2} \quad , \text{ and} \\ \frac{\partial \bar{v}}{\partial t} &= - f(u - u_G) + \nu_T \frac{\partial^2 \bar{v}}{\partial z^2} \end{aligned} \tag{4.21}$$

It is appropriate to write (4.21) as:

$$\left(\frac{\partial}{\partial t} + if - \nu_T \frac{\partial^2}{\partial z^2} \right) \chi = if \chi_G \tag{4.22}$$

where $\chi = \bar{u} + i\,\bar{v}$

The time-dependent solutions of (4.22) have been extensively studied by meteorologists since the classical work of Ekman . In the stationary state (4.22) becomes

$$\frac{\partial^2}{\partial z^2} \xi - \frac{if}{\nu_T} \xi = 0 \quad , \tag{4.23}$$

with $\xi = \chi - \chi_G$. The boundary conditions are:

$\xi \to 0$ when $z \to \infty$

$\xi \to -\chi_G$ when $z \to 0$

and the solutions of Eq. (4.23) are:

$$\bar{u}(z) = G(1 - e^{-kz} \cos kz) \quad , \text{ and}$$

$$\bar{v}(z) = G\,e^{-kz}\sin kz \quad ,$$

where $k = (f/\nu_T)^{1/2}$ is the inverse of a length parameter, the Ekman depth.

The wind hodograph in the horizontal plane is the equiangular spiral first obtained by G. I. Taylor, and shown in Fig. 4.3.

4.3.4 Improved K-Type P.B.L. Models

It is well known that the assumption of a constant effective diffusivity is a crude representation of the effect of turbulence upon the averaged motion. In consequence many workers have tried to improve the original Eman-Taylor model by means of more descriptive turbulent friction stresses.

The simplest versions of these models consider a stationary neutrally-stratified P.B.L., ignore vertical changes in ρ_0, neglect viscous stresses with respect to turbulent stresses, and make use of the eddy diffusivity for momentum, K define as

$$Km = -\overline{uw}/\frac{\partial\bar{u}}{\partial z} \quad \text{, which} \tag{4.24}$$

is supposed to have the same value in both the x and y directions.

The initial system becomes:

$$f(\bar{v} - v_G) + \frac{\partial}{\partial z}\left(K\,\frac{\partial\bar{u}}{\partial z}\right) = 0$$

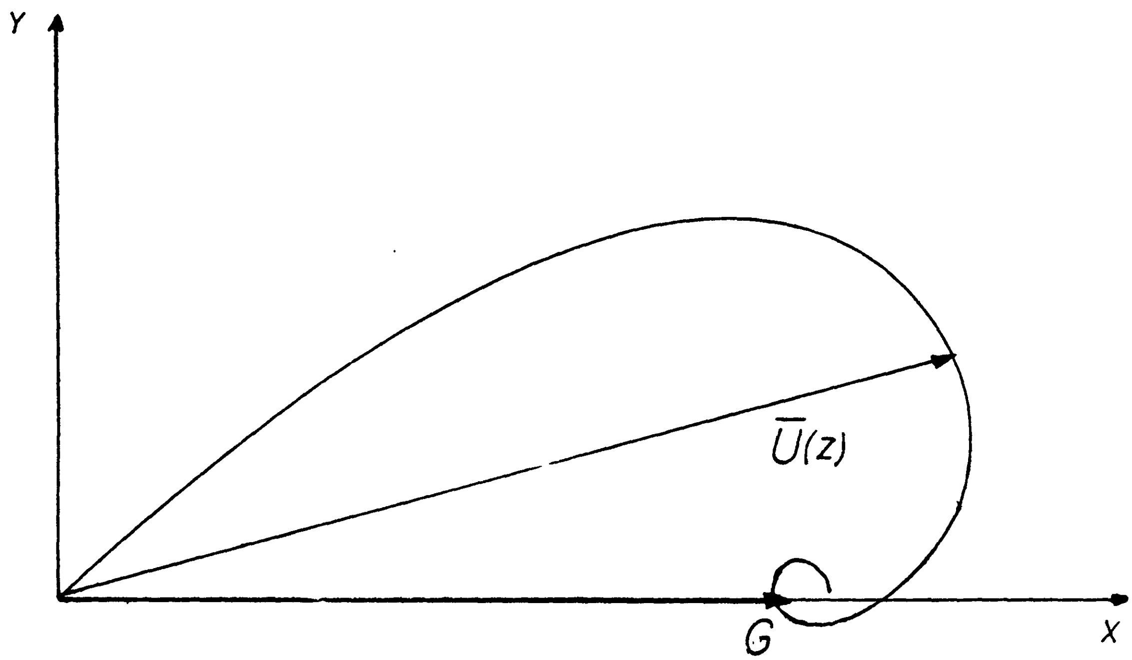


FIGURE 4.3

Equiangular Spiral ox Aligned with the Geostrophic Wind G

$$- f(\bar{u} - u_G) + \frac{\partial}{\partial z}\left(K\,\frac{\partial \bar{v}}{\partial z}\right) = 0 \tag{4.25}$$

To close the system, K has to be given as a function of $\bar{u}$, $\bar{v}$, and z. The approach is to use Prandtl's classical mixing-length theory, as:

$$K = \ell^2\,\left\{\left(\frac{\partial \bar{u}}{\partial z}\right)^2 + \left(\frac{\partial \bar{v}}{\partial z}\right)^2\right\}^{1/2} \quad , \tag{4.26}$$

the problem being to describe properly the variation of ℓ, the mixing length as a function of height.

The wind distribution in the immediate vicinity of the ground must be considered first. The direction and magnitude of the shear stress can be taken as constant in lower layers. So taking the surface stress τ_0 in the ox direction equation (4.26) becomes

$$\ell^2\left(\frac{\partial \bar{u}}{\partial z}\right)^2 = \frac{\tau_0}{\rho_0} = u^{*2} \quad , \tag{4.27}$$

where $u^* = \left(\frac{\tau_0}{\rho_0}\right)^{1/2}$ is the friction velocity characteristic of surface stresses. Thus, one has the result

$$\ell^2(z)\,\frac{\partial \bar{u}}{\partial z} = u^* \tag{4.28}$$

However it is known that the mixing length is proportional to the distance from the boundary, with a proportionality constant equal to k_0, k_0 being the von Karman constant.

$$\ell(z) = k_0 z \quad .$$

We therefore obtain the result

$$\frac{\partial \bar{u}}{\partial z} = \frac{u^*}{k_0 z} \quad ,$$

which can also be expressed as

$$\bar{u}(z) = \bar{u}(z_1) + \frac{u^*}{k_0} \ln \frac{z}{z_1} \quad , \tag{4.29}$$

where z_1 is a reference length. It is clear that Eq. (4.29) cannot be valid down to $z = 0$. In the case of a rough surface the difficulty is overcome by introducing a conventional reference elevation z_0, where $\bar{u}$ is supposed to go to zero. This yields the result

$$\bar{u}(z) = \frac{u^*}{k_0} \ln \frac{z}{z_0} \quad .$$

We see that the description of the wind structure in the P.B.L. requires not only the knowledge of the friction velocity, u^*, but also the introduction of a new basic parameter characteristic of the roughness of the underlying surface, the "roughness length."

Upon consideration of the velocity distribution in the outer part of the P.B.L., it becomes apparent that $\ell(z)$ cannot grow indefinitely when z increases, but has to be limited at some value related to the height of the P.B.L. Usually the height dependence of the mixing length is taken from experimental evidence. Blackadar (1962) has suggested the relationship

$$\ell(z) = \frac{k_0(z + z_0)}{1 + k(z + z_0)/\lambda} \quad , \tag{4.30}$$

where λ is given as

$\lambda = 2.7\ 10^5\ G/f$, where

G = Geostrophic wind and

f = Coriolis parameter.

The simplest K-type P.B.L. models [40,41,42] ignore the influence of density stratification upon turbulent-transfer processes, and are therefore only applicable to a neutral planetary P.B.L. The improved K-type models [42,43,44] take into account stratification effects, either by means of empirical relationship between eddy diffusivities and mixing lengths and such stratification parameters as flux or gradient Richardson numbers, or by making use of semi-empirically closed simple versions of the turbulent kinetic energy equation.

Another capability of improved K-type theories is the possibility to relax the restrictive assumption of stationarity, and horizontal homogeneity which had been made previously. In conjunction with modern computing techniques, and with empirical models of the radiative flux field, they can give very interesting representation of the diurnal velocity and of the influence of spatial inhomogeneities of the surface.

4.3.4.1 Inclusion of Stratification Effects

As soon as heat and moisture fluxes are significantly different from zero, stratification affects turbulent exchanges. The addition of stratification-generated turbulence requires at this level another degree of sophistication in the modelling of the shear stresses. At this point it is important to take a systematic approach in the modelling of the turbulence parameters in order to account properly for the complexity of the physical phenomena involved. From first principles one may acquire the different transport equation for the shear stresses, including the turbulence production and destruction terms. This part of the analysis is carried out in detail in the next section.

4.4 Experimental Data on the Mean and Turbulent Structure of the P.B.L.

Even before the era of modern instrumental techniques, a large number of studies on the average dynamical and thermal structure of the P.B.L. had been made with the aid of manned or unmanned balloons, kites, and instrumented towers, and some insight had even been gained into the turbulent structure. It is interesting to note that the vertical distribution of vertical shear stresses within the P.B.L. can be directly obtained from the mean velocity profile alone, by means of a simple integral of equations (4.14), (4.15) which gives:

$$\tau_{xz} = \tau_0 - \int_0^z \rho f(\bar{v} - v_G)\,dz \tag{4.31}$$

$$\tau_{yz} = \int_0^z \rho f\,(\bar{u} - u_G)\,dz \tag{4.32}$$

This is the so-called "geostrophic departive method." More recent studies have included not only extensive use of balloon-borne radiosondes and dropsondes, but also direct measurement of the turbulent structure by means of towers and aircraft equipped with fast-response instruments. There exist now a large number of well-instrumented micrometeorological towers with heights of order 150 meters, and some up to 300 and even 500 meters [45,56].

Experimental P.B.L. data show at first sight a rather disconcerting variety, which is largely due to the fact that the conditions for stationarity, and horizontal homogeneity have not been fulfilled. It is only when observations are being taken over a truly flat and horizontally homogeneous terrain, under truly stationary mesoscale conditions, and in the absence of "thermal wind" effects that a simple picture, directly related to the idealized P.B.L. description given above, begins to emerge.

The most obvious difference between the simple theoretical model and the experimental data is that the former assumes the P.B.L. to be stationary while the latter shows that, even under strictly steady mesoscale conditions, the P.B.L. is subject to an important diurnal variation. This variation can clearly be ascribed to the diurnal change in the radiative heat input at ground level: during daytime, solar radiation warms the ground, which becomes warmer than air, so that the turbulent heat flux is directed upward; then, during the night the ground loses heat by infrared radiation, and becomes cooler than air, with a resulting downward heat flux. In consequence, even with the very crude model of a thermal diffusivity which is constant in time and space, the turbulent heat flux has to be considered as changing in magnitude and sign as a function of altitude and of the hour in the day. In a similar way as the conductive heat flux in the classical problem of a medium subjected to a sinusoidally varying temperature at its boundary.

If we now recall that stratification effects are of prominent importance over most of the P.B.L., it is clear that the effective turbulent diffusivity, and in consequence the velocity distribution, are themselves subjected to an appreciable diurnal variation. The situation can be roughly sketched as follows. At the end of the night, the entire P.B.L. is in a state of strongly stable stratification (inversion), so that turbulence is nearly entirely suppressed. In the first hours of the day, solar heating begins to build a strongly variable layer near the ground, responsible for a high turbulent activity which very efficiently mixes momentum, heat, and moisture up to a given level. As the day goes on, the convectively-mixed layer progressively grows and erodes the above remains of the nocturnal inversion. The P.B.L. height therefore progressively increases, and reaches its maximum during the midday hours. Late in the afternoon, the solar heat supply is diminishing so that a kind of equilibrium is reached and the whole P.B.L. is not far from neutral stratification, with a slight inversion at the highest levels. Shortly after sunset, the sign of gravitational turbulent production is changed, so that the level of turbulence rapidly decreases. The thickness of the mixed layer rapidly decreases, while a strongly stable layer begins to build itself from the ground. As the night goes on, the upper and lower inversions finally merge, leaving very little turbulence near the end of the night

Hence the P.B.L.'s behavior is dominated by two inherently unsteady processes. The first one is the progressive erosion of a stable region by a convectively unstable mixed layer. The second is the progressive suppression of turbulence under the effect of a stable density gradient. It is therefore clear that the steady-state description of the P.B.L. can be valid only during relatively short times, and this explains the mentioned discrepancies between theory and experiments. The process is in fact still more complicated: divergence of solar and infrared radiative heat fluxes are important, and a diurnal change is also present in the turbulent water vapor flux (with a tendency to evaporation during daytime and condensation at night so that the gravitational effects are additive to those of turbulent heat flux).

These processes will be, of course, much less pronounced above the sea, where the diurnal temperature change of surface temperature is smaller by at least one order of magnitude. We can therefore ex expect a steady-state description of the P.B.L. to be more useful there.

4.5 Equations Governing the Planetary Boundary Layer

4.5.1 Why a One-Dimensional Model

The desire to model plumes in which diffusion is controlled by atmospheric turbulent fluctuations has led to the development of the Planetary Boundary Layer Turbulence model. Given the vertical atmospheric temperature, relative humidity and wind profiles the model yields the vertical Reynolds stress and the heat fluxe distributions. The plume generated turbulence in the computer mesh is calculated by means of a k-σ Turbulence model. The Atmospheric Turbulence field is stored in a library. At each time step and in each cell the plume-generated turbulence is compared with the atmospheric turbulence and the greater magnitude is taken as the actual turbulence level.

The equations which govern the planetary boundary layer are described in Chapter Two. The central problem, however, remains the choice of a proper closure model for the hierarchy of correlation functions. In this paragraph we develop a third order closure model for the one-dimensional case. The choice of a one-dimensional model is motivated by several factors:

- The cost of a two- or three-dimensional model is often prohibitively great. This is due essentially to the complexity of the physical phenomena involved in such a flow, in consequence of which the numerical calculations for a valid simulation are very laborious.

- Two-dimensional models have been developed previously [47,48], and it has been found [47, 48] that two-dimensional turbulence is quite different from three-dimensional turbulence. In particular two-dimensional models of Rayleigh convection in air predict steady-state Rayleigh numbers as large as 6×10^5 [49] whereas experimental observations show unsteady three-dimensional motion for Rayleigh numbers as small as 6×10^3 [50]. According to Deardorff [51], "If momentum flux is modeled in a two-dimensional plane, one finds no downward transport of momentum above the surface. However, observations indicate that the opposite occurs: wind gusts which are highly three-dimensional are evidenced overhead before they are felt at the surface." Because of such discrepancies between two-dimensional and three-dimensional turbulence, any two-dimensional model of turbulence in the P.B.L. must consider these problems if it is at all realistic. One-dimensional models have been prevalent for some time and account properly for these observations.

- It is not evident that three-dimensional models are an improvement over the one-dimensional models. One-dimensional models generally assume eddy coefficient, flux relationships which contain many limitations and uncertainties. The magnitude of the eddy coefficient and its dependence on thermal stability are generally not known above the surface layer. These objections are overcome in the second moment approach of Donaldson [52]. However the method suffers from the necessity to use a height-dependent mixing length which is chosen *a priori*, and it suffers also from all the uncertainties that arise in the experimentally-obtained universal constants of the closure models. However the latter difficulty is not unique to one-dimensional models since it is inherent in the necessity of formulating classic assumptions themselves. Thus two- and three-dimensional problems experience the same difficulty of formulating closure relations. One clear advantage of three-dimensional models lies in the fact that the condition of defining the height-dependent mixing length is relaxed by the choice of a proper scale for the subgrid eddy coefficient [53].

4.5.2 The Governing Equations

4.5.2.1 Introduction

In Chapter Two we have seen that the mean flow equations contained the components of the Reynolds stress which so far are unknown in this problem. We can treat these terms by finding equations which govern the stresses or velocity correlations. It is found that the equations which govern the Reynolds stresses contain two types of unknowns: the correlations of the second order and correlation of the third order. They arise from the nonlinearity of the Navier-Stokes equations. In order to reduce the number of unknowns to the number of independent equations the third order correlations are expressed in terms of correlations of lower orders through phenomenological relationships. This is due to the fact that linear relationships are chosen (this is not always true [51]) to model the correlations, which are forced to respect the following conditions:

- The expression chosen must exhibit the symmetric tensor character of the Reynolds stress.
- It must be dimensionally correct.
- It must be invariant under a general transformation of coordinates, as well as under a Gallilean transformation.

- It must not be such as to upset any of the general conservation laws.

It is beyond the scope of this work to present a complete description of the method of invariant modelling. However, in the next paragraph a brief outline of the method is presented, as well as a short discussion of its relationship to the mixing length model of turbulent transport proposed by Prandtl [52].

The first-order closure problem consists of finding a relationship between Reynolds stresses and first-order moments and their derivatives. If we assume that the magnitude of the momentum flux ($\overline{u \cdot v}$) is small, we can in an approximation take only the first-order derivatives and assume a linear dependence of the coefficients of this function on the turbulent viscosities, which are now unknown quantities. In the case of the energy equation, one makes the hypothesis that the ratio of the turbulent momentum transfer to the turbulent heat transfer is the turbulent Prandtl number. This procedure decouples the Navier-Stokes equation from the thermodynamics equation.

The second-order closure consists of solving the partial differetnial equations which govern the second-order correlation and then solving the mean field equation. Solving the equations requires use of closure models, which are often obtained from physical interpretation of experiments. There will be no attempt to derive from first principles the different models used (for a review of the techniques used to construct the closure relations (see Donaldson [52]). However all of our models are relatively simple, and are based on the works of several authors [54,55].

Having written these equations with second-order correlations and having chosen the appropriate closure model. We reduce the equations to a one-dimensional set of coupled partial differential equations which we solve for the different correlations.

4.5.2.2 Second-Order Closure

The set of equations that we propose to solve is a variation from the Boussinesq set proposed in Chapter Three (eqs. 3.34 - 3.41).

A basic weakness of the plume model, which is being addressed in this part of the current work is a description of atmospheric turbulence. The user of the plume model must specify the structure (vertical) of the atmosphere (in terms of velocity, temperature, moisture and turbulence quantities). Consequently the quality of the results depends strongly on how insightful the user is. However a basic weakness is the prescription of the turbulence structure since the necessary data are not usually measured in field experiments. It is however imperative to account properly for turbulence if the results are to be at all reliable.

The idea behind this approach is a two-fold procedure. In the first step we assume that the temperature and velocity profiles are steady, at least on a time-scale large compared to the time required for turbulent adjustment. If this is so, we may in the equation for the second-order moment assume that $\bar{u}(z)$ and $\bar{T}(z)$ are the given profiles. These equations can then be solved for the time variations of these correlations themselves. The solution is continued until the derivatives of the correlations with respect to time approach zero. The resulting distributions of the second-order correlations are taken to be the appropriate distributions for any atmosphere whose mean profiles of $\bar{u}(z)$ and $\bar{T}(z)$ are those given by field measurements.

Eqs. (3.39) - (3.41) may then be solved for the one-dimensional case in which we will assume the mean velocity to be parallel to the surface in the x-z plane; thus, $\bar{v} = 0 = \bar{w}$. We will consider the motion to be independent of x and y, and hence a function only of z (height) and t (time). Consequently $\partial/\partial y = \partial/\partial x = 0$; henceforth the turbulent transport equations become:

$$\frac{D\overline{uu}}{Dt} = - \overline{wu}\,\frac{\partial \bar{u}}{\partial z} - \overline{wu}\,\frac{\partial \bar{u}}{\partial z} - \frac{\partial}{\partial z}\,(\overline{uwu}) + \nu_0\,\frac{\partial^2 \overline{uu}}{\partial z^2} - 2\nu_0\,\overline{\frac{\partial u}{\partial z}\,\frac{\partial u}{\partial z}} \quad , \quad (4.32)$$

$$\frac{D\overline{vv}}{Dt} = - \frac{\partial}{\partial z}\,(\overline{vwv}) + \nu_0\,\frac{\partial^2 vv}{\partial z^2} - 2\nu_0\,\overline{\frac{\partial v}{\partial z}\,\frac{\partial v}{\partial z}} \quad , \qquad (4.33)$$

$$\frac{D\overline{ww}}{Dt} = - \frac{\partial}{\partial z}\,(\overline{www}) - \frac{2}{\rho_0}\,\frac{\partial}{\partial z}\,(\overline{pw}) + \frac{2}{T_0}\,(\overline{gwT}) + \nu_0\,\frac{\partial^2 ww}{\partial z^2}$$

$$- 2\nu_0 \overline{\left(\frac{\partial w}{\partial z}\,\frac{\partial w}{\partial z}\right)} \quad , \qquad (4.34)$$

$$\frac{D}{Dt}\,\overline{uw} = - \overline{ww}\,\frac{\partial \bar{u}}{\partial z} - \frac{\partial}{\partial z}\,(\overline{uww}) - \frac{1}{\rho_0}\,\frac{\partial}{\partial z}\,(\overline{pu}) + \frac{p}{\rho_0}\,\overline{\left(\frac{\partial u}{\partial z}\right)}$$

$$+ \nu_0\,\frac{\partial^2 \overline{uw}}{\partial z^2} - 2\nu_0 \overline{\left(\frac{\partial u}{\partial z}\,\frac{\partial w}{\partial z}\right)} \quad , \qquad (4.35)$$

$$\frac{D}{Dt}\,\overline{uv} = - \overline{wv}\,\frac{\partial \bar{u}}{\partial z} - \frac{\partial}{\partial z}\,(\overline{uwv}) + \nu_0\,\frac{\partial^2 \overline{uv}}{\partial z^2} - 2\nu_0 \overline{\left(\frac{\partial u}{\partial z}\,\frac{\partial v}{\partial z}\right)} \quad , \qquad (4.36)$$

$$\frac{D}{Dt}\,\overline{vw} = - \overline{wv}\,\frac{\partial \bar{u}}{\partial z} - \frac{\partial}{\partial z}\,(\overline{vww}) - \frac{1}{\rho_0}\,\frac{\partial}{\partial z}\,(\overline{pv}) + \frac{p}{\rho_0}\,\left(\frac{\partial v}{\partial z}\right)$$

$$+ \frac{1}{T_0}\,(g\,\overline{vT}) + \nu_0\,\frac{\partial^2 \overline{vw}}{\partial z^2} - 2\nu_0 \overline{\left(\frac{\partial v}{\partial z}\,\frac{\partial w}{\partial z}\right)} \quad , \qquad (4.37)$$

$$\frac{D}{Dt}\,\overline{uT} = - \overline{wu}\,\frac{\partial T}{\partial z} - \overline{wT}\,\frac{\partial \bar{u}}{\partial z} - \frac{\partial}{\partial z}\,(\overline{wuT}) + \nu_0\,\frac{\partial^2 \overline{uT}}{\partial z^2} - 2\nu_0 \overline{\left(\frac{\partial u}{\partial z}\,\frac{\partial T}{\partial z}\right)} \; , \quad (4.38)$$

$$\frac{D}{Dt}\overline{vT} = -\overline{wv}\frac{\partial\bar{T}}{\partial z} - \frac{\partial}{\partial z}(\overline{wvT}) + \nu_0\frac{\partial^2\overline{vT}}{\partial z^2} - 2\nu_0\overline{\left(\frac{\partial v}{\partial z}\frac{\partial T}{\partial z}\right)} \quad , \tag{4.39}$$

$$\frac{D}{Dt}\overline{wT} = -\overline{ww}\frac{\partial\bar{T}}{\partial z} - \frac{\partial}{\partial z}(\overline{wwT}) - \frac{1}{\rho_0}\frac{\partial}{\partial z}(\overline{pT}) + \overline{\frac{p}{\rho_0}\frac{\partial T}{\partial z}} + \frac{1}{T_0}g\,\overline{T^2}$$

$$+ \nu_0\frac{\partial^2}{\partial z^2}\overline{wT} - 2\nu_0\left(\frac{\partial w}{\partial z}\frac{\partial T}{\partial z}\right) \quad , \text{ and} \tag{4.40}$$

$$\frac{D}{Dt}\overline{T^2} = -2\overline{wT}\frac{\partial\bar{T}}{\partial z} - \frac{\partial}{\partial z}(\overline{wT^2}) + \nu_0\frac{\partial^2\overline{T^2}}{\partial z^2} - 2\nu_0\overline{\left(\frac{\partial T}{\partial z}\frac{\partial T}{\partial z}\right)} \quad . \tag{4.41}$$

Note that if some means can be found to model in the above equations the velocity diffusion terms, the terms containing pressure fluctuations (i.e. the tendency toward entropy terms and the pressure diffusion terms), and the dissipation terms, in terms of the mean variable and/or the second-order correlations of the variables, then the set of equations given above will be closed and a solution, in principle, can be found for the mean quantity $\bar{u}$ and $\bar{T}$, as well as for all the second-order order quantities.

In the following section the problem of choosing such a model is discussed.

4.5.2.3 Selection of Models

It is beyond the scope of this thesis to present the detailed description of the method of invariant modeling of correlations. However the idea behind it is described in the following example:

Prandtl expressed the second-order correlation function $\rho\overline{u_i u_j}$

in terms of mean velocity field by means of a physical argument [54] and obtained the well-known result

$$- \rho \overline{uv} = \rho \ell^2 \left|\frac{\partial \bar{u}}{\partial y}\right| \frac{\partial \bar{u}}{\partial y} \tag{4.42}$$

where ℓ is a scale parameter identified in the argument with a characteristic size of the turbulent scale.

One can obtain this result in another way, by asking whether one can write the tensor $\overline{u_i u_j}$ in terms of mean motion $\bar{u}_i$. The expression chosen must exhibit the symmetric tensor character of $\overline{u_i u_j}$, must be dimensionally consistent, must be invariant under a general transformation of coordinates, and must not upset any of the general conservation laws.

One finds that the tensor

$$\varepsilon_{ij} = \frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i} \tag{4.43}$$

has the required symmetry and satisfies the invariance conditions so one can write

$$\overline{u_i u_j} = f(\bar{u}_k) \left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right) \tag{4.44}$$

where $f(u_k)$ is a scalar and must be such that the dimensions of the resulting expression are consistent. One possibility is:

$$f(\bar{u}_k) = \Lambda^2 \sqrt{\varepsilon_{ij}\, \varepsilon_{ij}} \tag{4.45}$$

In this expression, Λ is a scalar measure of length. If the formula given above is reduced to the situation of simple shear layer $\bar{u} = \bar{u}(y)$ with $\bar{v} = \bar{w} = 0$, one obtains

$$- \overline{uv} = \sqrt{2}\, \Lambda^2 \left| \frac{\partial \bar{u}}{\partial y} \right| \frac{\partial \bar{u}}{\partial y} \quad , \tag{4.46}$$

which is essentially the Prandtl result. One concludes, therefore, that Eq. (4.44) is a general form of Prandtl's mixing length expression for the Reynolds stress.

The higher order correlations can be expressed in the same manner. We start with the velocity diffusion terms. We wish to model the tensor $\overline{u_i u_j u_k}$ in terms of the second-order correlations $\overline{u_i u_k}$. The simplest tensor of rank three tnat can be obtained from $\overline{u_i u_k}$ that has the same symmetries in all thre indices is

$$\overline{u_i u_j u_k} \approx \frac{\partial}{\partial x_i} \overline{u_j u_k} + \frac{\partial}{\partial x_j} \overline{u_k u_i} + \frac{\partial}{\partial x_k} \overline{u_i u_j} \quad . \tag{4.47}$$

This expression has all of the required tensor characteristics for the model but is not dimensionally consistent. To make the dimensions consistent, we must multiply the right hand side of (4.47) by a scalar with dimensions of length times velocity. A simple scalar velocity obtainable from the second-order correlation is:

$$q = \sqrt{\overline{u_m u_m}} = \sqrt{\overline{u_1 u_2} + \overline{u_2 u_2} + \overline{u_3 u_3}} \tag{4.48}$$

Finally, if we multiply this expression by a scalar Λ which is to be related to the mean motion or to the scale of turbulence, we form a simple model of the triple correlation

$$\overline{u_i u_j u_k} = -\Lambda^2 q\left[\frac{\partial}{\partial x_i}(\overline{u_j u_k}) + \frac{\partial}{\partial x_j}(\overline{u_i u_k}) + \frac{\partial}{\partial x_k}(\overline{u_i u_j})\right] \tag{4.49}$$

This formulation is due to Donaldson [52].

Let us consider a model for the triple correlation $\overline{u_j u_k T}$. Using the same approach as that for $\overline{u_i u_j u_k}$ one defines a tensor that has all the symmetry properties of $\overline{u_j u_k T}$.

$$\overline{u_j u_k T} \approx \frac{\partial}{\partial x_j}\overline{u_k T} + \frac{\partial}{\partial x_k}\overline{u_j T} \tag{4.50}$$

then adjusting the dimensions of the righthand side with the dimensions of $\overline{u_j u_k T}$, we obtain the result

$$\overline{u_j u_k T} = -\Lambda_2 q\left[\frac{\partial}{\partial x_j}\overline{u_k T} + \frac{\partial}{\partial x_k}\overline{u_j T}\right] \tag{4.51}$$

In order to keep the model as simple as possible it is necessary to use in the model as few length scales as possible. Therefore Λ_2 is taken as the scale for all velocity diffusion terms.

The other important correlation to model is the pressure-velocity gradient correlations. These terms have been first interpreted as tendency toward isotropy tensors, since these terms tend to destroy the Reynolds stresses by redistributing the fluctuations isotropically. Rotta, who was the first to give this interpretation, proposed an expression where the deviation from the Reynolds stress measures the anisotropy.

$$\overline{\frac{p}{\rho_0}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)} = -\frac{q}{\Lambda_1}\left(\overline{u_i u_j} - \delta_{ij}\frac{q^2}{3}\right) \tag{4.52}$$

However, the contribution of the pressure velocity fluctuations is slightly more complicated than it appears at the first glace and involves a velocity of deformation effect, derived by Crow [56] for Nearey isotropic turbulence. Henceforth (4.21) becomes

$$\overline{\frac{p}{\rho_0}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)} = -\frac{q}{\Lambda_1}\left(u_i u_j - \delta_y \frac{q^2}{3}\right) + c_v \tag{4.53}$$

where the Crow-Lilly theory gives:

$$c_v = \frac{2}{5}\, q^2 \left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right) \tag{4.54}$$

The molecular dissipation term is also important whenever one considers the destruction of turbulence. From Lumley [57], the small-scale structure which produces correlations between gradients of fluctuating velocities can be considered as isotropic. A simple expression which would account for the following terms:

$$\overline{\frac{\partial u_i}{\partial x_k}\frac{\partial u_j}{\partial x_k}}\ , \quad \overline{\frac{\partial u_i}{\partial x_k}\frac{\partial T}{\partial x_k}}\ , \quad \overline{\frac{\partial T}{\partial x_k}\frac{\partial T}{\partial x_k}} \tag{4.55}$$

would be of the form

$$\overline{\frac{\partial A}{\partial x_k}}\,\overline{\frac{\partial B}{\partial x_k}} = \frac{\overline{AB}}{\lambda^2} \tag{4.56}$$

where A and B represent fluctuating field quantities (u_i, T), and λ is a length scale. In the absence of a justification for further complexity one wishes to keep the value of λ the same for the dissipation terms in all of the conservation equations.

Although Deardorff [53] neglects the pressure velocity fluctuations correlations in his model, they are taken into account in our model. However little is known concerning these terms. Donaldson [52] proposes a "nonproductive model," i.e., the model is depends upon the gradient of the quantity in the equation for which we are trying to model the pressure diffusion term. Thus he chooses the relationships

$$\overline{pu_k} = - \rho_0 \, q \, \Lambda_3 \frac{\partial}{\partial x_i} \overline{u_i u_k} \quad , \text{ and} \tag{4.57}$$

$$\overline{pT} = - \rho_0 \, q \, \Lambda_3 \frac{\partial}{\partial x_i} \overline{u_i T} \quad . \tag{4.58}$$

Before we can proceed further it is necessary to make more precise the details of the model of turbulent atmospheric flow that has just been presented. However we will confine ourselves to presenting the origin of our set of parameters.

4.5.2.4 Search for Model Parameters

To obtain the model parameters, one constructs models for some well-known flows and compares the results to experimental data. In this way one determines relationships between the various scales Λ_i and λ by choosing these parameters so as to give the best results for the widest number of experimental observations.

The parameters that we will be using have been obtained by Donaldson [57] by comparing computations with experimental results for three shear flows:

- the axially symmetric free jet,
- the two-dimensional free shear layer, and
- the flat-plate boundary layer.

The length scales are chosen such that

$$\Lambda_1 = c_1 \delta_{char} \quad , \tag{4.59}$$

$$\Lambda_2 = c_2 \Lambda_1 = c'_2 \delta_{char} \quad , \tag{4.60}$$

$$\Lambda_3 = c_3 \Lambda_1 = c'_3 \delta_{char} \quad , \text{ and} \tag{4.61}$$

$$\lambda = \Lambda_1 \Big/ (a + b \, Re_{\Lambda_1})^{1/2} \quad , \tag{4.62}$$

where δ_{char} is a characteristic length scale such that

$$Re_{\Lambda_1} = \rho q \Lambda_1 / \mu \tag{4.63}$$

A relation (4.62) between the dissipative scale λ and the isotropy scale Λ_1 is required so that as the Reynolds number of the flow increases, dissipation will keep pace with the other productive and diffusive terms in the equation. This form of relationship between λ and Λ_1 has been used previously by Glushko [58].

The surface boundary condition

$$\overline{u_i u_j}\Big|_{z=0} = 0 \qquad (4.64)$$

obtains, where z is measured normal to the surface. Also at the surface there should be no turbulent diffusion of $u_i u_j$. This yields the condition

$$\frac{\partial}{\partial z}\overline{u_i u_j}\Big|_{z=0} = 0 \qquad (4.65)$$

Therefore close to the surface we have $\overline{u_i u_j} = A_{ij}\, z^{1+\eta}$ (4.66), where A_{ij} is a constant and η a positive constant. Henceforth all the momentum flux diffused toward the wall by viscosity at $z = \varepsilon$ is assumed to be dissipated between $z = \varepsilon$ and $z = 0$.

Thus, we have the result

$$2\mu \int_0^{\varepsilon} \frac{\overline{u_i u_j}}{\lambda^2}\, dz = \mu \left(\frac{\partial}{\partial z}\overline{u_i u_j}\right)_{z=\varepsilon} \qquad (4.67)$$

Thus using eq. (4.66) we obtain the result

$$2 \int_0^{\varepsilon} \frac{z^{1+\eta}}{\lambda^2}\, dz = (1+\eta)\, \varepsilon^{\eta} \quad , \qquad (4.68)$$

which when $\varepsilon \to 0$ takes the form

$$\lambda = \alpha z \quad , \tag{4.69}$$

where $\alpha^2 = 2/(1+\eta)\eta$. Hence near a solid surface we always assume that Eq. (4.69) holds in the region near the wall. However it is more convenient to use this result in terms of the scale, Λ_1. Near the wall Eq. (4.62) takes the form

$$\lambda = \Lambda_1/a^{1/2} \quad , \tag{4.70}$$

or using Eq. (4.69) we have

$$\Lambda_1 = (\alpha a^{1/2})\, z \quad . \tag{4.71}$$

However several expressions for Λ^1 have been suggested in the literature which incorporate al‐ the above information and which are more consistent in the sense th‐t one does not need to specify a cutoff height above which the mixing length should be constant. Among these we have chosen the expression due to Blackadar [59]:

$$\Lambda_1 = \frac{k_0(z+z_0)}{1+\dfrac{k_0(z+z_0)}{\xi}} \tag{4.72}$$

where ξ is an eddy length scale, and k_0 is the von Karman constant, which in the context of this model is taken to be equal to

$$k_0 = \alpha a^{1/2} \quad .$$

Note that for small value of the height $\Lambda_1 = k_0(z+z_0)$, where z_0 is the roughness parameter (taken to be equal to zero for smooth surfaces).

When z becomes larger Λ_1 becomes

$$\Lambda_1 = \xi \quad .$$

Blackadar proposed the expression

$$\xi = \frac{27\,Vg \times 10^{-5}}{f} \quad ,$$

where Vg is the magnitude of the geostrophic wind and f is the coriolis parameter.

However as stated in Eq. (4.51) $\Lambda_1 = c_1\,\delta_{char}$. Hence in our case we have the result

$$\xi = c_1\,\delta_{char} \tag{4.73}$$

Therefore, the length scale $\Lambda_1(z)$ is written as

$$\Lambda_1(z) = \frac{\alpha a^{1/2}(z+z_0)}{1+\dfrac{\alpha a^{1/2}(z+z_0)}{\xi}} \tag{4.74}$$

From experimental results Donaldson [52] has obtained the following values of the free parameters in the model.

$$a = 2.5 \quad ,$$

$$b = 0.125 \quad ,$$

$$c_2 = 0.1 \quad ,$$

$$c^3 = 0.1 \quad ,$$

$c_1 = \Lambda_1/\delta_{099} = 0.15$, and

$\alpha = 0.7/a^{1/2} = 0.443$.

Given the different models for the velocity fluctuation correlation we now have all the elements to build a turbulent planetary boundary layer model

4.5.2.5 The Model Equations

Upon substitution of the closure assumptions, Eqs. (4.32) through (4.41) take the following form:

$$\frac{D}{Dt}\,\overline{uu} = -\,2\,\overline{uw}\,\frac{\partial\bar{u}}{\partial z} + \frac{\partial}{\partial z}\left(\Lambda_2\, a\,\frac{\partial}{\partial z}\,\overline{uu}\right) - \frac{q}{\Lambda_1}\left(\overline{uu} - \frac{q^2}{3}\right)$$
$$+\ \nu_0\,\frac{\partial^2}{\partial z^2}\,\overline{uu} - 2\nu_0\,\frac{\overline{\quad}}{\lambda^2}\quad , \tag{4.75}$$

$$\frac{D}{Dt}\,\overline{vv} = \frac{\partial}{\partial z}\left(\Lambda_2\, q\,\frac{\partial}{\partial z}\,\overline{vv}\right) - \frac{q}{\Lambda_1}\left(\overline{vv} - \frac{q^2}{3}\right) + \nu_0\,\frac{\partial^2}{\partial z^2}\,\overline{vv}$$
$$-\ 2\nu_0\,\frac{\overline{vv}}{\lambda^2}\quad , \tag{4.76}$$

$$\frac{D}{Dt}\,\overline{ww} = \frac{2g}{T_0}\,\overline{wT} + 3\,\frac{\partial}{\partial z}\left(\Lambda_2\, q\,\frac{\partial}{\partial z}\,\overline{ww}\right) + 2\,\frac{\partial}{\partial z}\left(\Lambda_3\, q\,\frac{\partial}{\partial z}\,\overline{ww}\right)$$
$$-\ \frac{q}{\Lambda_1}\left(\overline{ww} - \frac{q^2}{3}\right) + \nu_0\,\frac{\partial^2}{\partial z^2}\,\overline{ww} - 2\nu_0\,\frac{\overline{ww}}{\lambda^2}\quad , \tag{4.77}$$

$$\frac{D}{Dt}\,\overline{uw} = -\,\overline{ww}\,\frac{\partial\bar{u}}{\partial z} + \frac{g}{T_0}\,\overline{uT} + 2\,\frac{\partial}{\partial z}\left(\Lambda_2\, q\,\frac{\partial}{\partial z}\,\overline{uw}\right)$$
$$+\ \frac{1}{\rho_0}\,\frac{\partial}{\partial z}\left(\rho_0\,\Lambda_3\, q\,\frac{\partial}{\partial z}\,\overline{uw}\right) - \frac{q}{\Lambda_1}\,\overline{uw} + \nu_0\,\frac{\partial^2}{\partial z^2}\,\overline{uw}$$

$$- 2\nu_0 \frac{\overline{uw}}{\lambda^2} \quad , \tag{4.78}$$

$$\frac{D}{Dt}\overline{uT} = - \overline{uw}\frac{\partial \bar{T}}{\partial z} - \overline{wT}\frac{\partial \bar{u}}{\partial z} + \frac{\partial}{\partial z}\left(\Lambda_2 q \frac{\partial}{\partial z}\overline{uT}\right) - \frac{q}{\Lambda_1}\overline{uT}$$

$$+ \nu_0 \frac{\partial^2}{\partial z^2}\overline{uT} - 2\nu_0 \frac{\overline{uT}}{\lambda^2} \quad , \tag{4.79}$$

$$\frac{D}{Dt}\overline{wT} = - \overline{ww}\frac{\partial \bar{T}}{\partial z} + \frac{g}{T_0}\overline{T^2} + 2\frac{\partial}{\partial z}\left(\Lambda_2 q \frac{\partial}{\partial z}\overline{wT}\right)$$

$$+ \frac{1}{\rho_0}\frac{\partial}{\partial z}\left(\rho_0 \Lambda_3 q \frac{\partial}{\partial z}\overline{wT}\right) - \frac{q}{\Lambda_1}\overline{wT} + \nu_0 \frac{\partial^2}{\partial z^2}\overline{wT}$$

$$- 2\nu_0 \frac{\overline{wT}}{\lambda^2} \quad , \text{ and} \tag{4.80}$$

$$\frac{D}{Dt}\overline{T^2} = - 2\overline{wT}\frac{\partial \bar{T}}{\partial z} + \frac{\partial}{\partial z}\left(\Lambda_2 q \frac{\partial}{\partial z}\overline{T^2}\right) + \nu_0 \frac{\partial^2 \overline{T^2}}{\partial z^2} - 2\nu_0 \frac{\overline{T^2}}{\lambda^2} \quad . \tag{4.81}$$

4.6 Model Solution Methodology

4.6.1 Numerical Methods

The turbulence model equations for one dimensional flow can be written in conservation form as:

$$\frac{\partial R}{\partial t} = \nabla(\alpha_R \nabla R) + S_r \quad , \tag{4.83}$$

where

$$R = \begin{bmatrix} \overline{UU} \\ \overline{VV} \\ \overline{WW} \\ \overline{UW} \\ \overline{UT} \\ \overline{WT} \\ \overline{TT} \end{bmatrix} , \quad \alpha_R = \begin{bmatrix} \Lambda_2 q+\nu_0 & & & & & & \\ & \Lambda_2 q+\nu_0 & & & & -0- & \\ & & 3\Lambda_2 q+2\Lambda_3 g+\nu_0 & & & & \\ & & & 2\Lambda_2 q+\Lambda_3 g+\nu_0 & & & \\ & & & & \Lambda_2 q+\nu_0 & & \\ & -0- & & & & 2\Lambda_2 q+\Lambda_3 q+\nu_0 & \\ & & & & & & 2\Lambda_2 q+\nu_0 \end{bmatrix}$$

and S_r is given on the following page.

$$
S_r = \begin{bmatrix}
-2\,\overline{UW}\,\frac{\partial \overline{U}}{\partial Z} - \frac{q}{\Lambda_1}\left\{\overline{UU} - \frac{q^2}{3}\right\} - 2\nu_0\,\frac{\overline{UU}}{\lambda^2} & & & & & \text{- 0 -} & \\
 & -\frac{q}{\Lambda_1}\left\{\overline{VV} - \frac{q^2}{3}\right\} - 2\nu_0\,\frac{\overline{VV}}{\lambda^2} & & & & & \\
 & & 2g\,\frac{\overline{WT}}{T_0} - \frac{q}{\Lambda_1}\left\{WW - \frac{q^2}{3}\right\} - 2\,\frac{\nu_0}{\lambda^2}\,\overline{WW} & & & & \\
 & & & -\overline{WW}\,\frac{\partial \overline{U}}{\partial Z} + \frac{g}{T_0}\,\overline{UT} - \frac{q}{\Lambda_1}\,\overline{UW} - \frac{2\nu_0}{\lambda^2}\,\overline{UW} + \Lambda_3 q\,\frac{\partial \overline{UW}}{\partial Z}\,\frac{\partial \log \rho_0}{\partial Z} & & & \\
 & & & & -\overline{UW}\,\frac{\partial \overline{T}}{\partial Z} - \overline{WT}\,\frac{\partial \overline{U}}{\partial Z} - \frac{q}{\Lambda_1}\,\overline{UT} - 2\nu_0\,\frac{\overline{UT}}{\lambda^2} & & \\
 & & & & & -\overline{WW}\,\frac{\partial \overline{T}}{\partial Z} + \frac{g}{T_0}\,\overline{TT} - \frac{q}{\Lambda_1}\,\overline{WT} - 2\nu_0\,\frac{\overline{WT}}{\lambda^2} + \Lambda_3 q\,\frac{\partial \overline{WT}}{\partial Z}\,\frac{\partial \log \rho_0}{\partial Z} & \\
 & \text{- 0 -} & & & & & -2\,\overline{WT}\,\frac{\partial \overline{T}}{\partial Z} - 2\nu_0\,\frac{\overline{TT}}{\lambda}
\end{bmatrix}
$$

Diagonal Elements of the Matrix S_r

This system of partial differential equations is solved by means of a two-step scheme. If the solution R_j^n is known at time $t = n\Delta t$ at each point of the computational mesh, (Fig. 4.4), an approximate intermediate solution is first obtained by solving the diffusion equation implicitly according to the relationship

$$\frac{\hat{R}_j - R_j^n}{\delta t} = \nabla\left(\alpha_{Rj}^n \ \nabla\hat{R}_j\right) \tag{4.84}$$

Writing explicitly the finite difference operators, the above equation can be written as follows:

$$A_j^n \hat{R}_{j-1} + B_j^n \hat{R}_j + C_j^n \hat{R}_j = R_j^n \quad , \tag{4.85}$$

where

$$A_j^n = -\lambda_{j-1}^n \ \alpha_{R_{j-1}}^n \ \frac{\Delta Z_{j-1}}{\Delta Z_j} \quad ,$$

$$B_j^n = (\Lambda + \lambda_j^n \ \alpha_{R_j}^n + \lambda_{j-1}^n \alpha_{R_{j-1}}^n \ \frac{\Delta Z_{j-1}}{\Delta Z_j} \quad ,$$

$$C_j^n = - \ \lambda_j^n \ \alpha_{R_j}^n \quad ,$$

$\lambda_j^n = \delta t/\Delta Z_j^2$, and ΔZ_j is the height increment.

The matrix of coefficients A_j^n, B_j^n, C_j^n is a tridiagonal matrix and the system (4.85) is readily solved by a Gaussian elimination method with a maximum of three variables per equation. The solution is straightforward.

Given the approximate solution, the exact solution can then be obtained by integrating the source term, as

$$\frac{R^{n+1} - \hat{R}}{\delta t} = S_{\hat{R}} \quad , \text{ or} \tag{4.86}$$

$$R^{n+1} = \hat{R} + \delta t S_{\hat{R}} .$$

4.6.2 Computational Domain

The basic requirement of the computational mesh is to be fine enough to resolve all significant spatial features of the problem. The computational domain is divided into a fine mesh near the wall and a coarse one away from it (see Fig. 4.4). The function $\hat{Z}$ is chosen in such a way that the difference between ΔZ of the coarse mesh and the maximum ΔZ of the fine mesh is relatively small but still allows enough resolution near the wall. The mesh lines are given by

$$Z_j = - \frac{\Lambda}{R_e^{1/2}} \text{Log} \left(1 - \frac{j-1}{\text{JLFM}} \right) \quad , \quad j = 1, 2, \ldots, \text{JLFM}$$

$$= \frac{\Lambda}{R_e^{1/2}} \text{Log} \left(1/\text{JLFM} \right) \quad , \quad j = \text{JLFM} + 1, \ldots, \text{JL}.$$

ΔZ_j appearing in the finite difference equations is

$$\Delta Z_j = (\hat{Z}_{j+1} - \hat{Z}_j) \ .$$

4.6.3 Initial and Boundary Conditions

The condition of zero momentum flux and zero double correlations

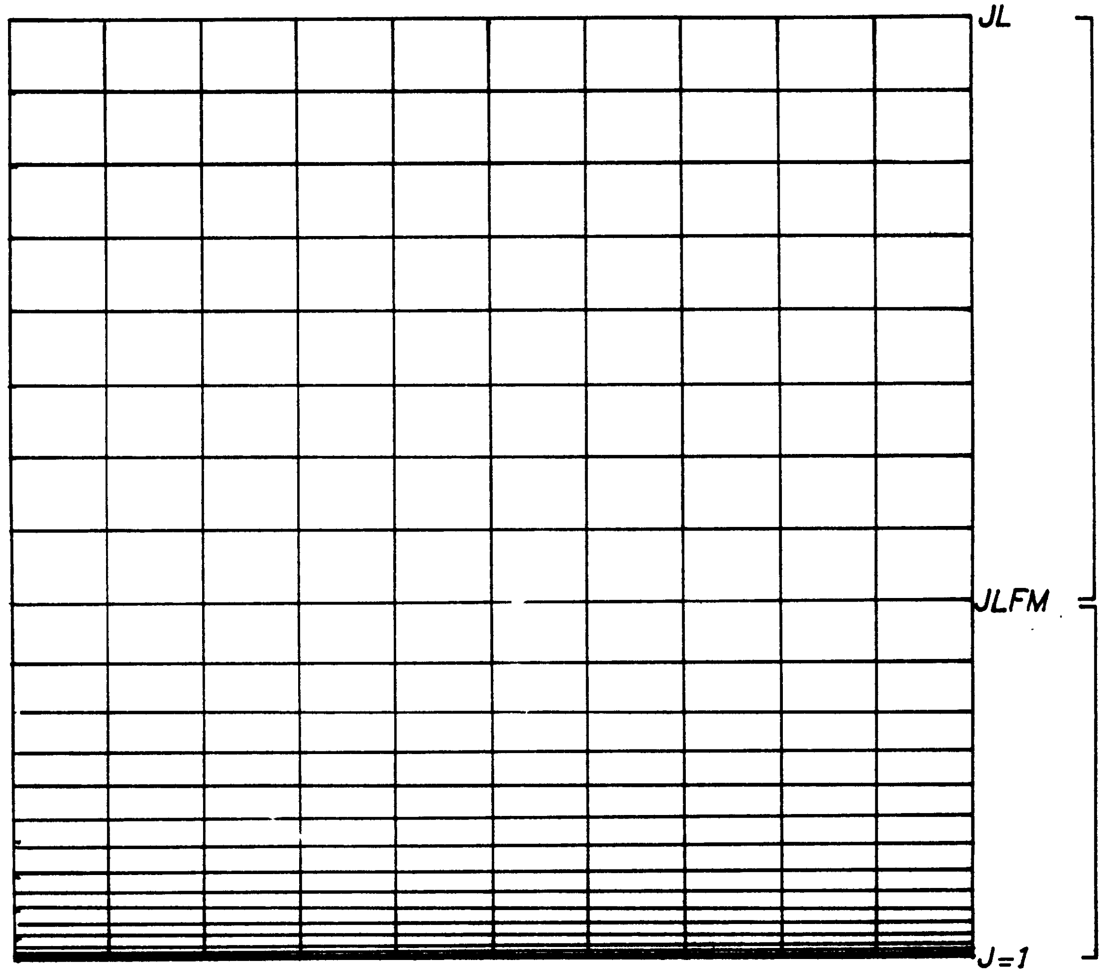


Figure 4.4

The Computational Mesh

at the ground have been described in sec. 4.5. A knowledge of the velocity and temperature profiles is required in order to avoid the need for solving the Navier-Stokes and energy equations in addition to the turbulence equations. The given profiles must be steady, at least on a time scale large compared to the time required for turbulent adjustment. These equations can be solved assuming any initial distribution for the turbulent correlations. The solution is continued until the derivatives of the correlations with respect to time approach zero. The resulting distributions of the second-order correlations are then taken to be the appropriate distributions for an atmosphere whose mean profile is $\overline{U}(z)$ and $\overline{T}(z)$. The computations are generally run with a small level of isotropic turbulence introduced in the system while the other correlations ($\overline{UW}$, $\overline{UT}$, $\overline{WT}$, $\overline{TT}$) are assumed to be zero initially.

4.6.4 Numerical Results and Discussion

In this work three cases of different atmospheric stability have been considered. The calculation can be illustrated by considering the case of stable atmosphere shown in Fig. 4.6. For this scale Λ (Z) has been chosen to be

$$\Lambda,(Z) = \frac{\alpha a^{1/2}(Z + Z_0)}{\Lambda + \alpha a^{1/2}(Z + Z_0)/\xi}$$

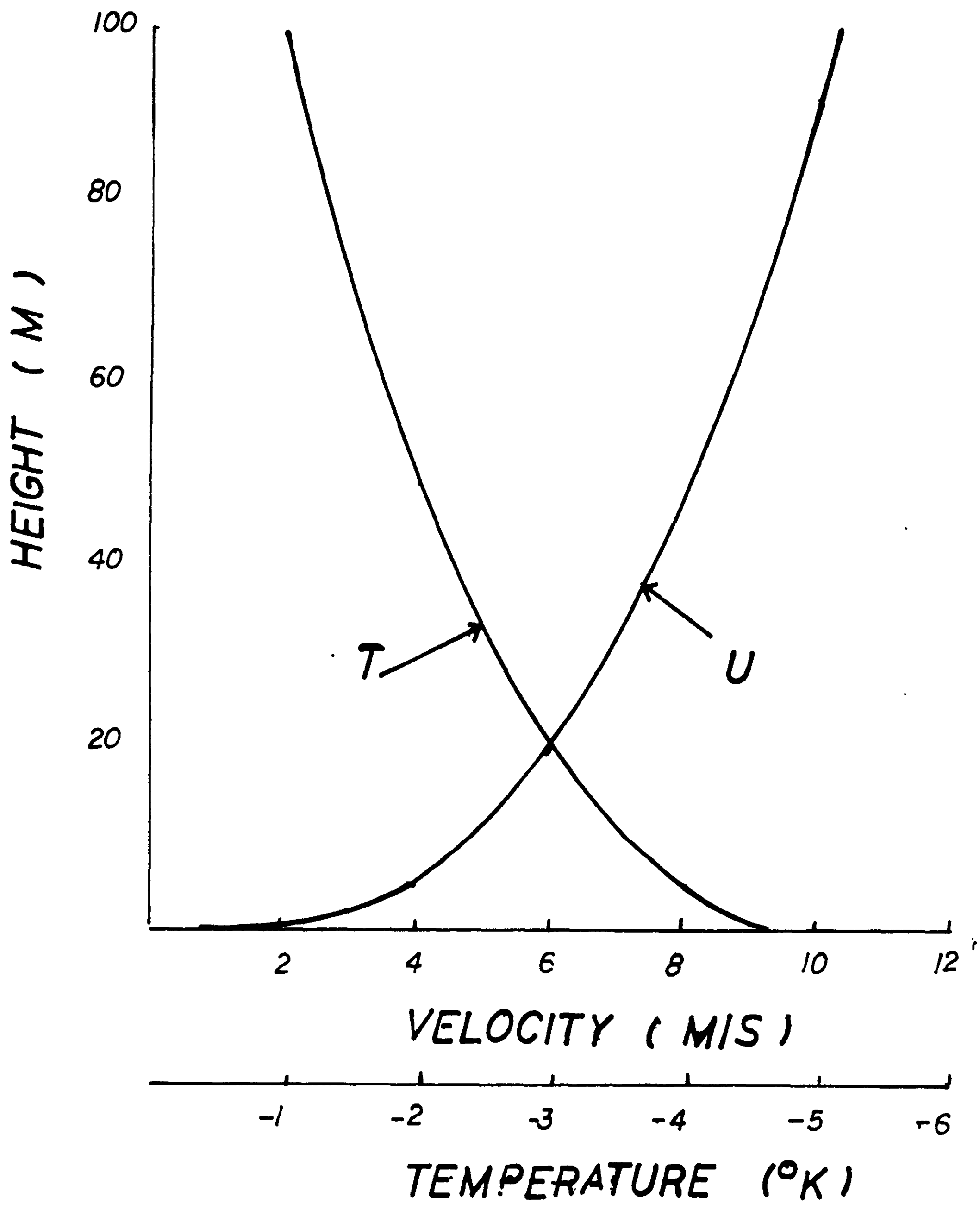


Figure 4.6

Mean Velocity and Mean Temperature
Profiles for the Stable Atmosphere

where α and a are the universal model parameters, Z_0 is a roughness coefficient and ξ is a length scale (for more details see paragraph 4.5.2.4). The prescription of the length scale ξ is somewhat arbitrary. In physical terms ξ is a measure of the height of the boundary layer. The actual measurements of the mean velocity profile do not permit such a height to be calculated systematically since experimental data are available only to a height of 22 m. Henceforth the data have been extrapolated using a logarithmic profile. Given the steady state wind profile, one can choose the characteristic length scale of the boundary layer as the height at which the mean velocity is 99% of the free-stream velocity. For this case the characteristic height has been found to be 100 m. Given these assumptions a computation of the turbulence properties of the Planetary Boundary Layer have been made according to the scheme outlined above. The results are shown in the solid lines in Figs. 4.7 - Fig. 4.14. It is seen that the order of magnitude of all quantities is estimated correctly. The agreement between the calculated and measured $\overline{uw}$, $\overline{ww}$, $\overline{uu}$, $\overline{vv}$ is reasonably good. It is interesting to note in this regard that the magnitudes of $\overline{uu}$ and $\overline{vv}$ as measured are alike, with $\overline{vv}$ more than twice $\overline{ww}$. The agreement between the measure results and computed values for the temperature correlations $\overline{uT}$, $\overline{wT}$, $\overline{T^2}$ is poor. The measured correlations are very small and the accuracy of these results may be questionable. For example the measured heat flux correlations are constant with height and extends beyond the region where any significant potential temperature gradient exists. The same comment applies for the neutral (Fig. 4.16 to Fig. 4.24) and for the unstable case (Fig. 4.25 to Fig. 4.33). However the model does best in the stable case.

Although these difficulties are seen to exist the model does better than most one-dimensional turbulence models available in the literature (52).

Figure 4.7

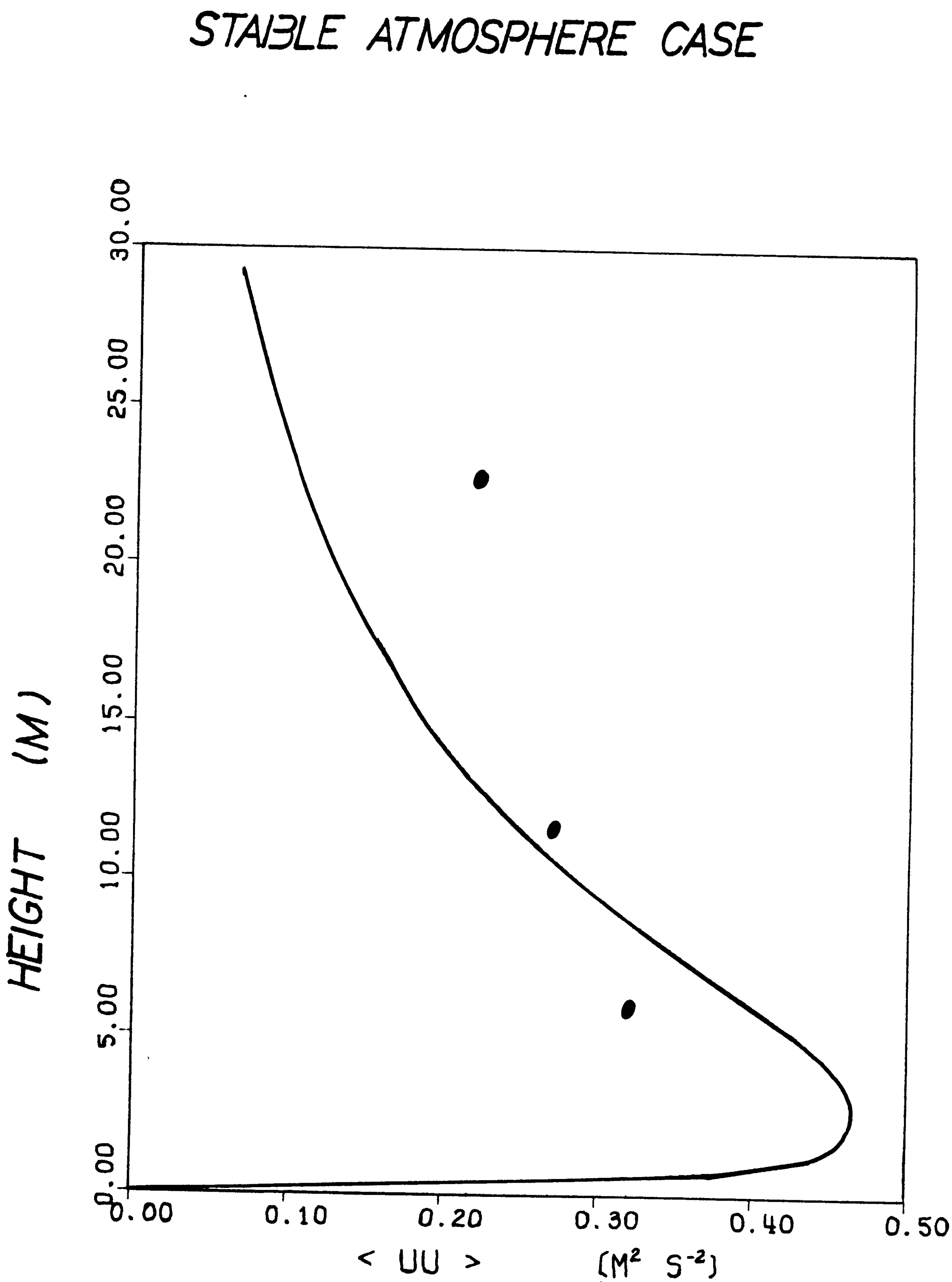
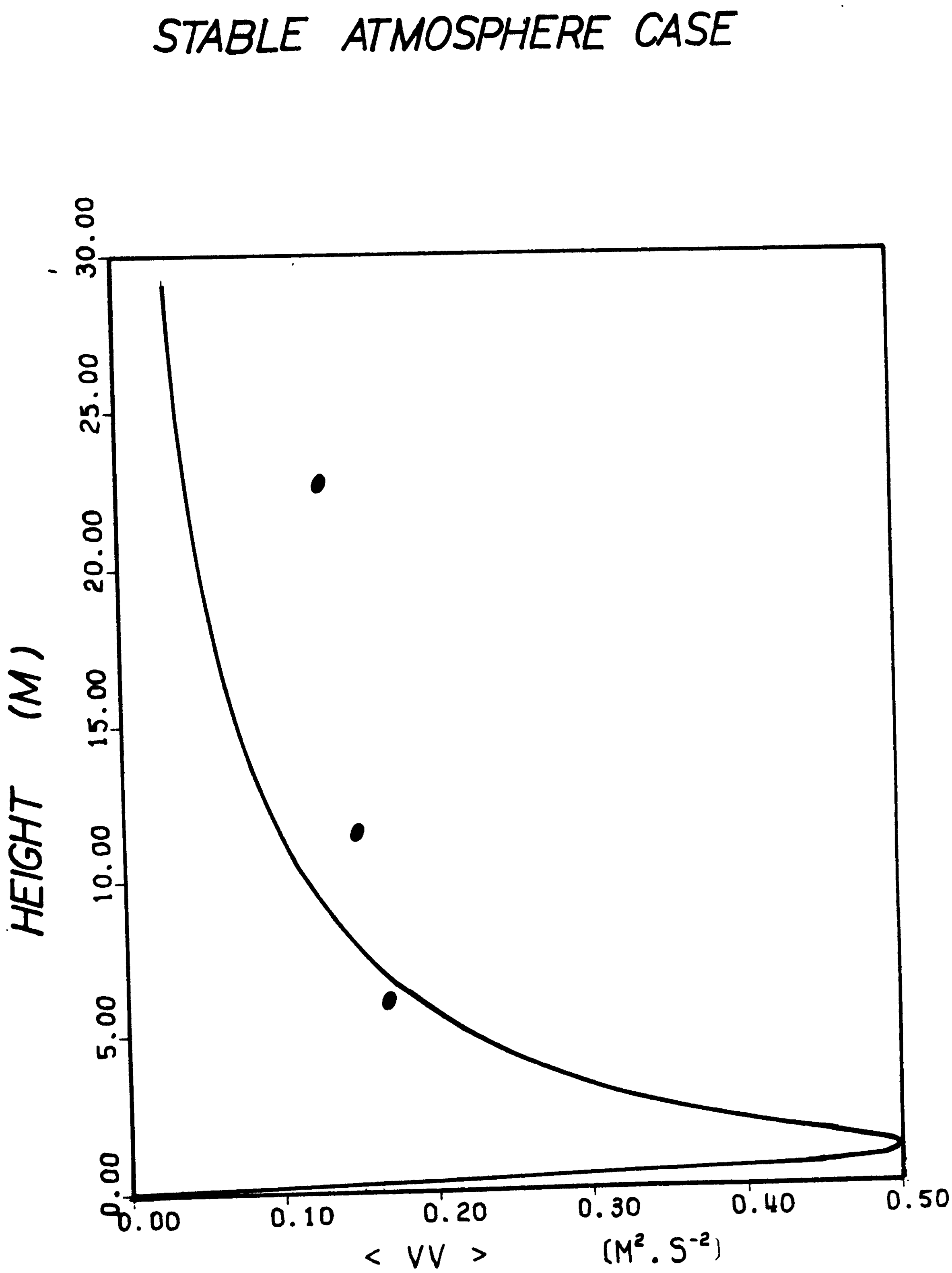

STABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.10
0.20
0.30
0.40
0.50
< UU > (M² S⁻²)

Figure 4.8



STABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.10
0.20
0.30
0.40
0.50
< VV > (M².S⁻²)

Figure 4.9

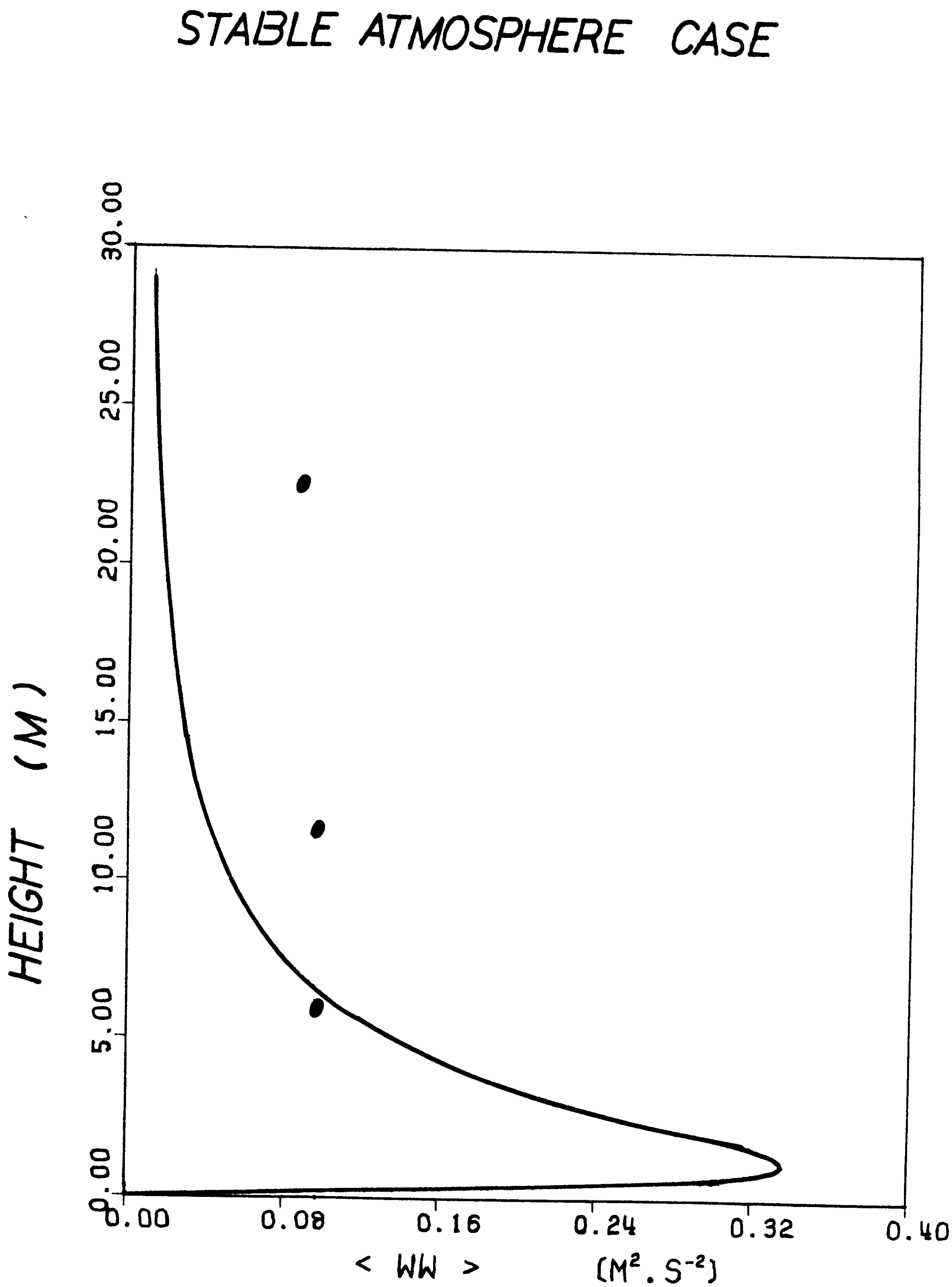

STABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.08
0.16
0.24
0.32
0.40
< WW > (M². S⁻²)

Figure 4.10

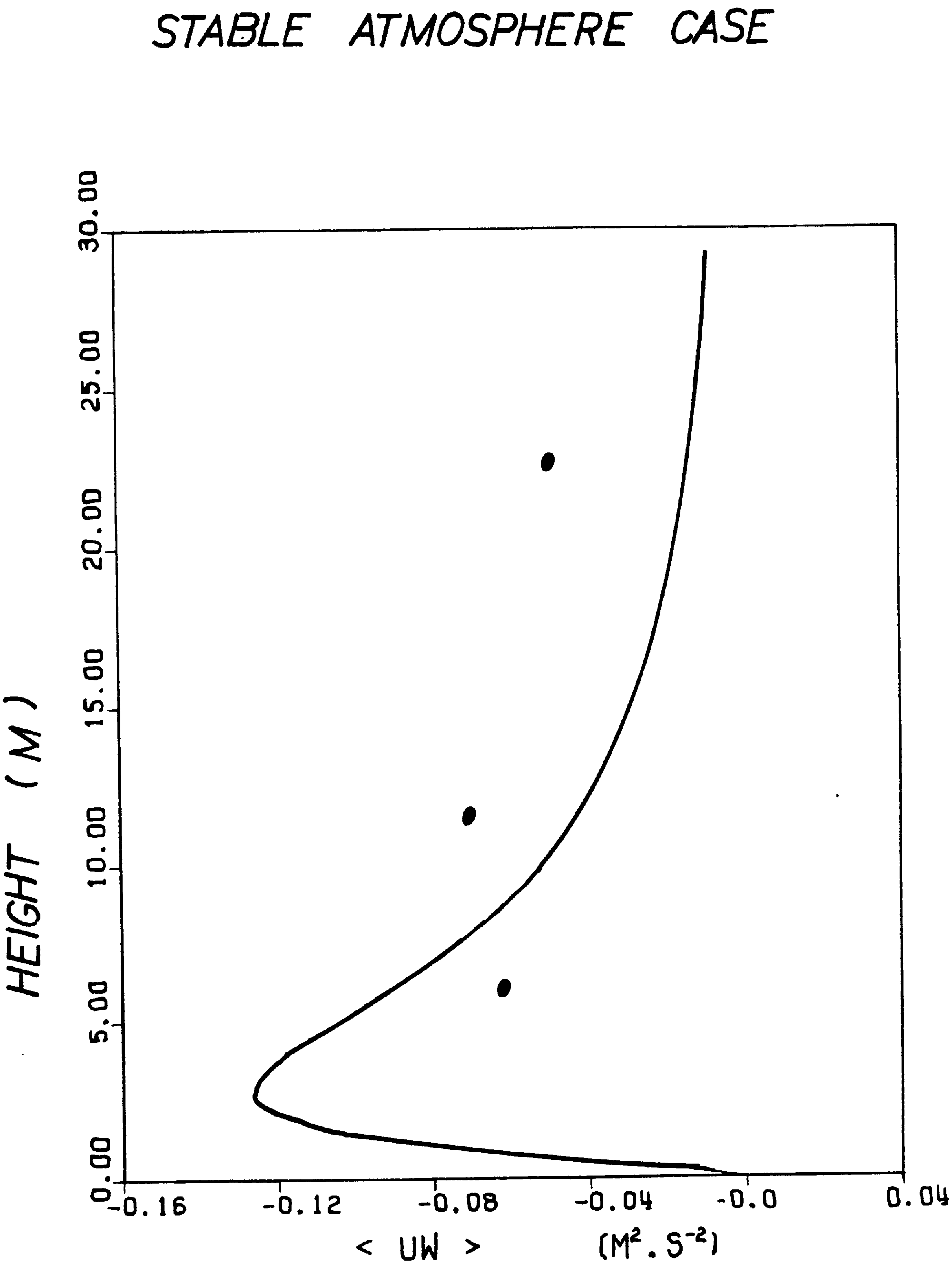
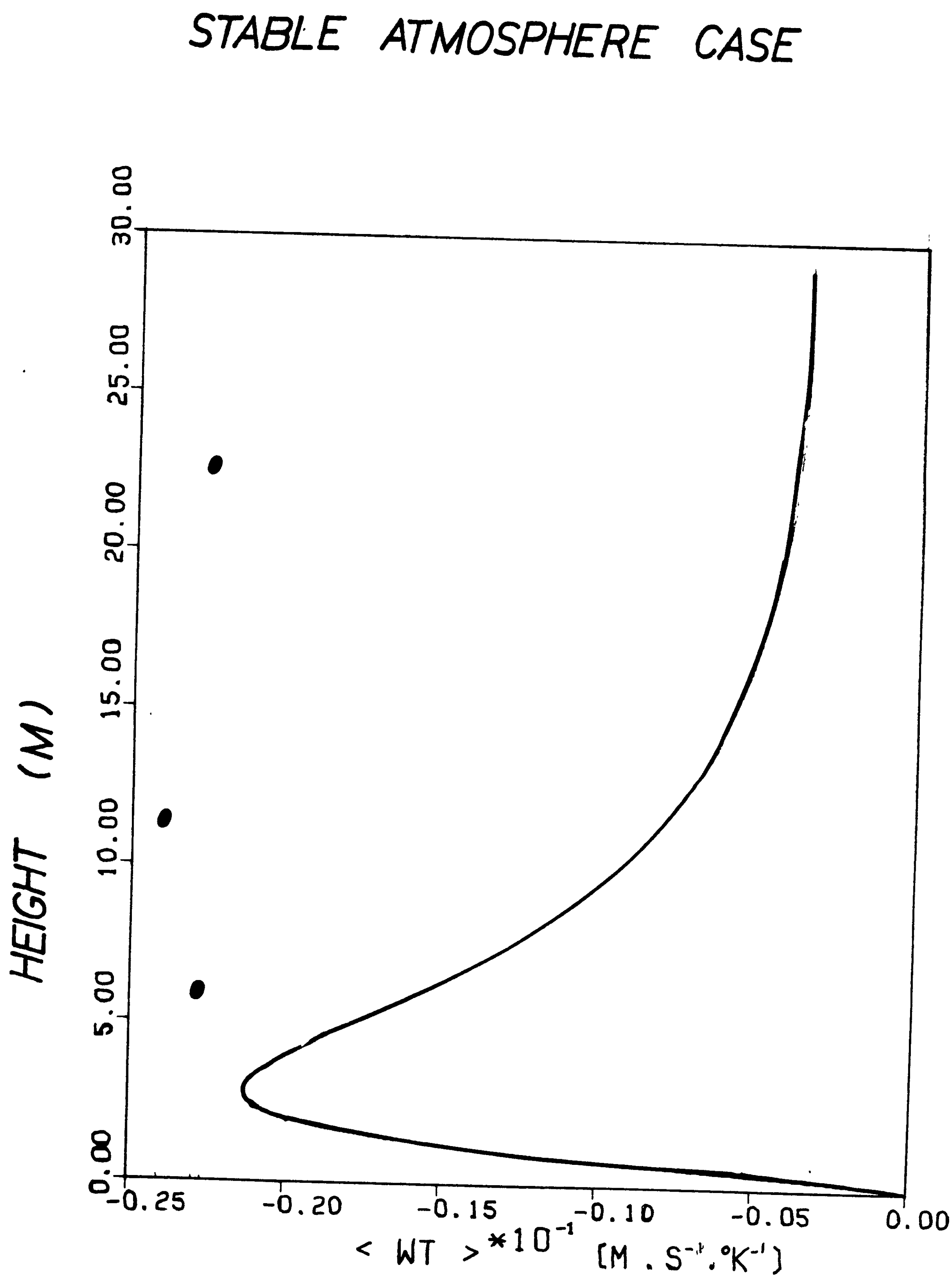

STABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
-0.16
-0.12
-0.08
-0.04
-0.0
0.04
< UW > (M².S⁻²)

Figure 4.11



STABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
< WT >*10^-1 [M . S^-1 . °K^-1]

Figure 4.12

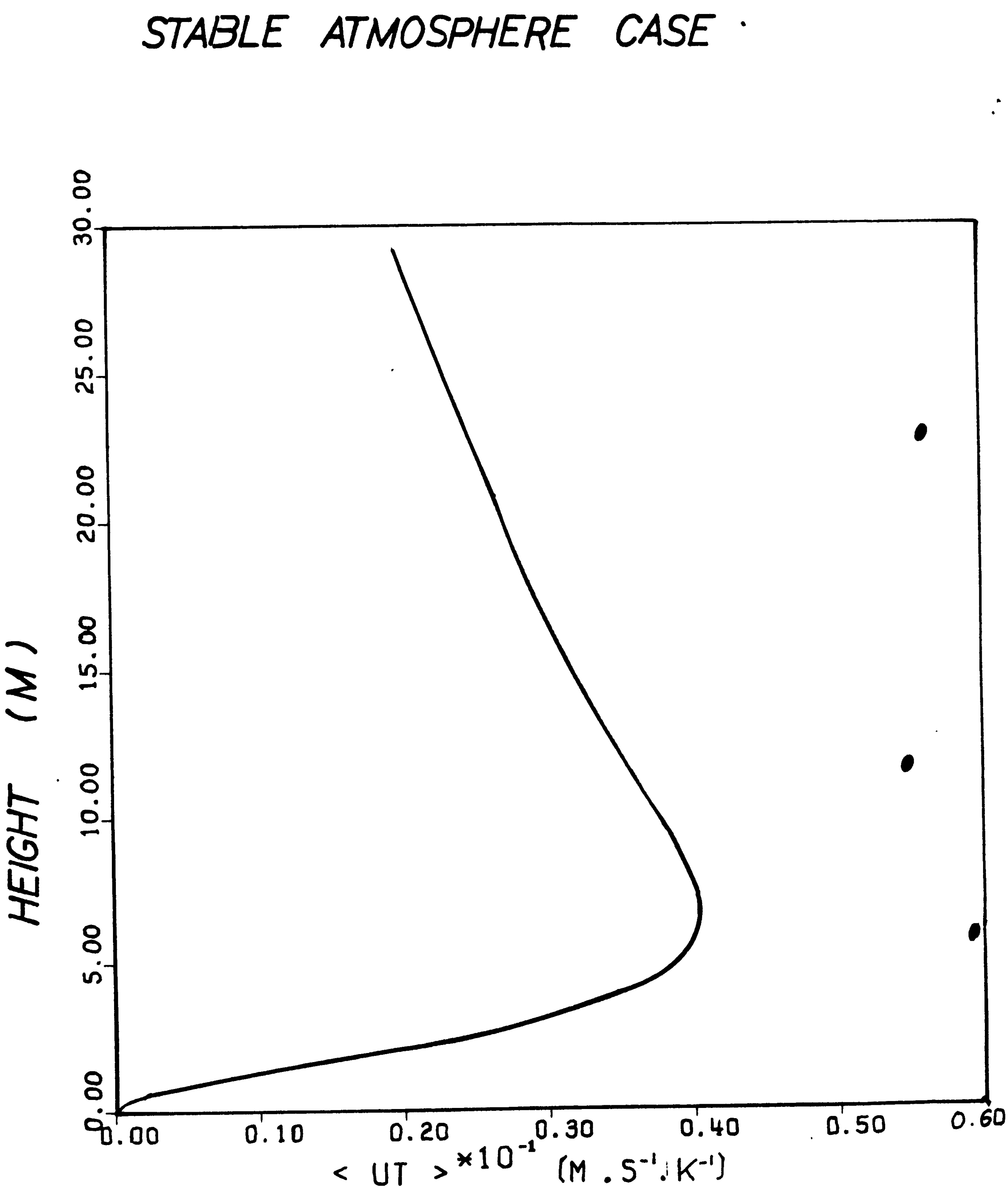

STABLE ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
< UT > *10^-1 (M . S^-1 . K^-1)

Figure 4.13

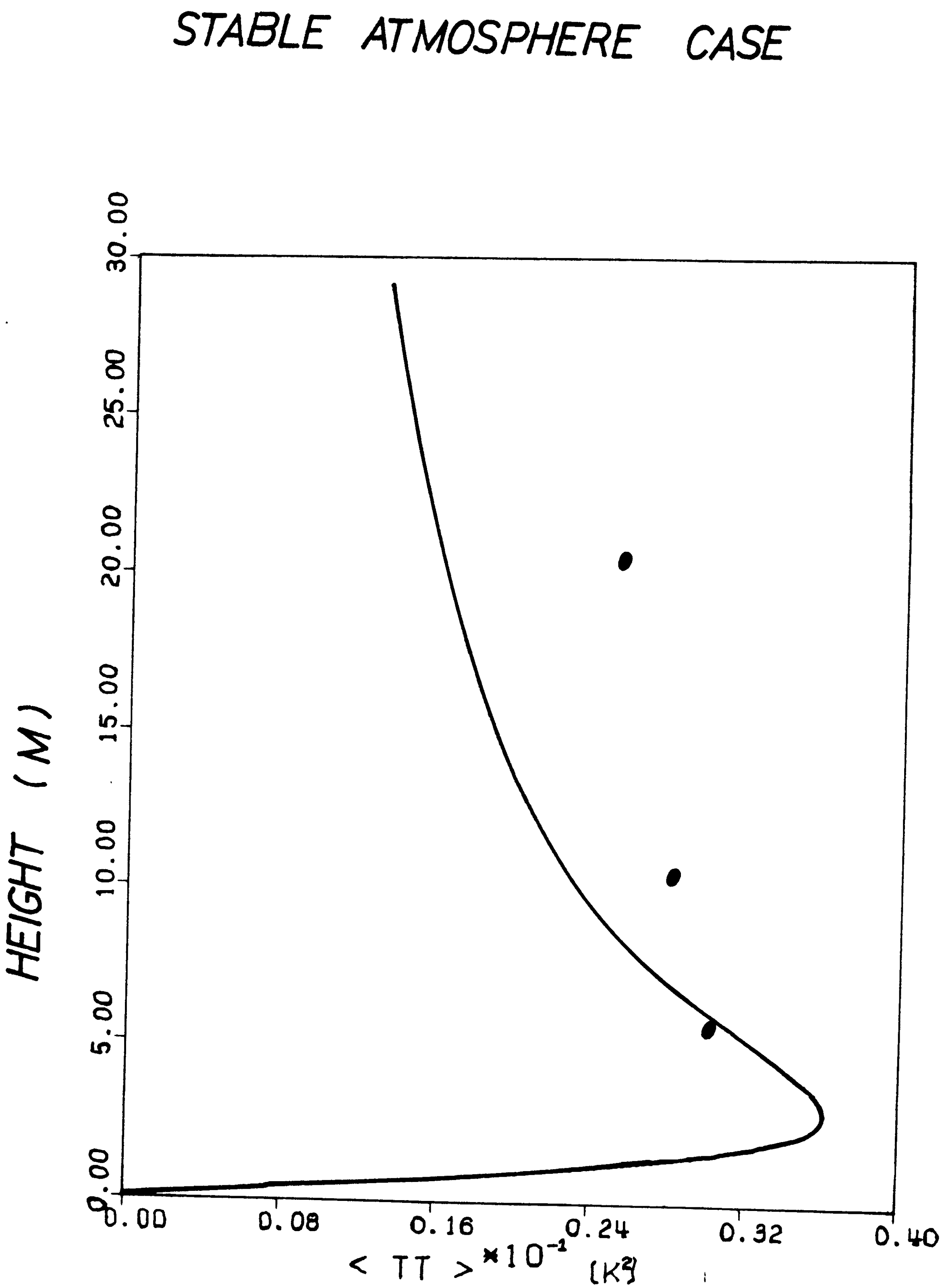
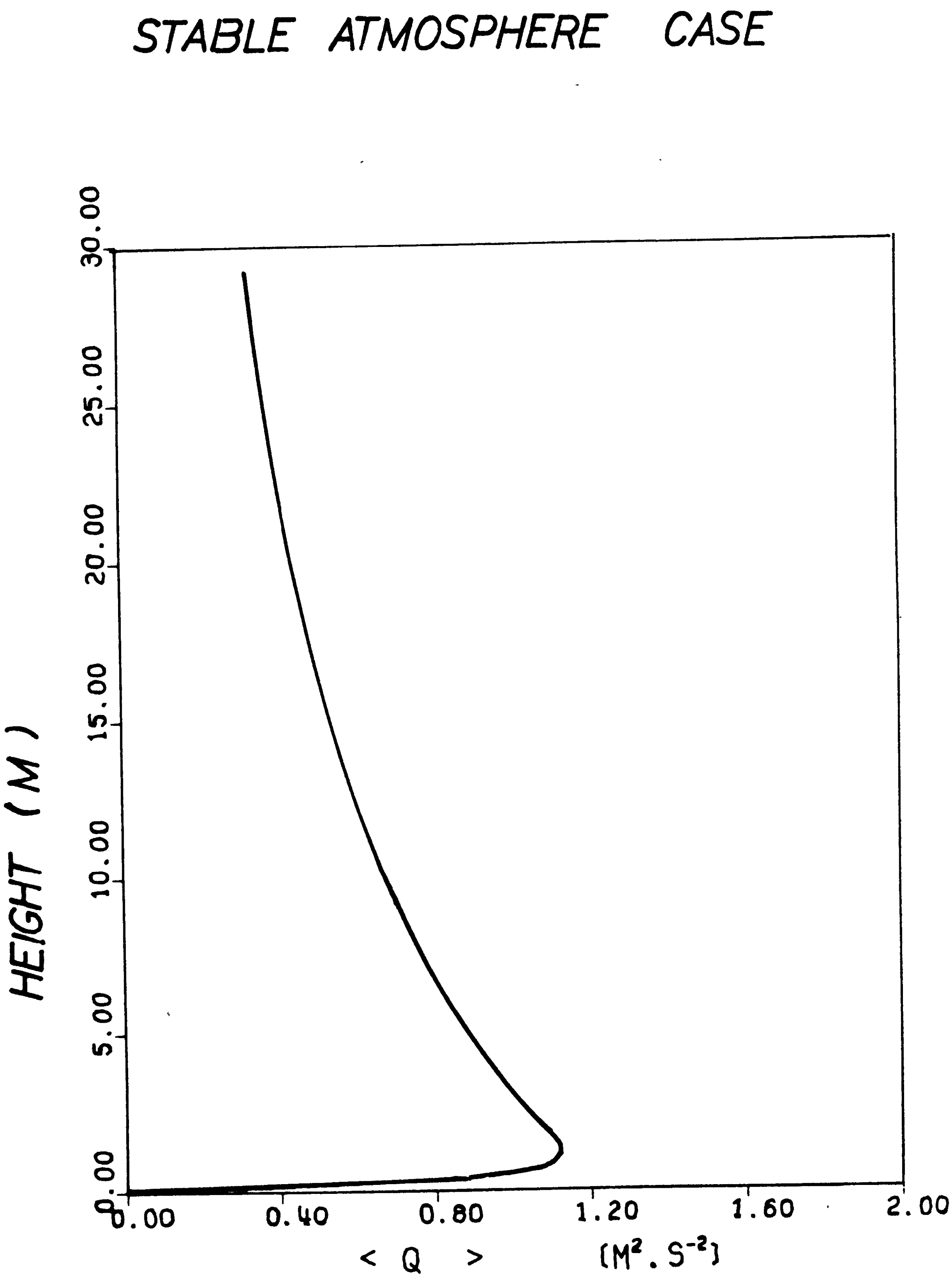

STABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.08
0.16
0.24
0.32
0.40
< TT > *10⁻¹ [K²]

Figure 4.14


STABLE ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.40
0.80
1.20
1.60
2.00
< Q >
[M². S⁻²]

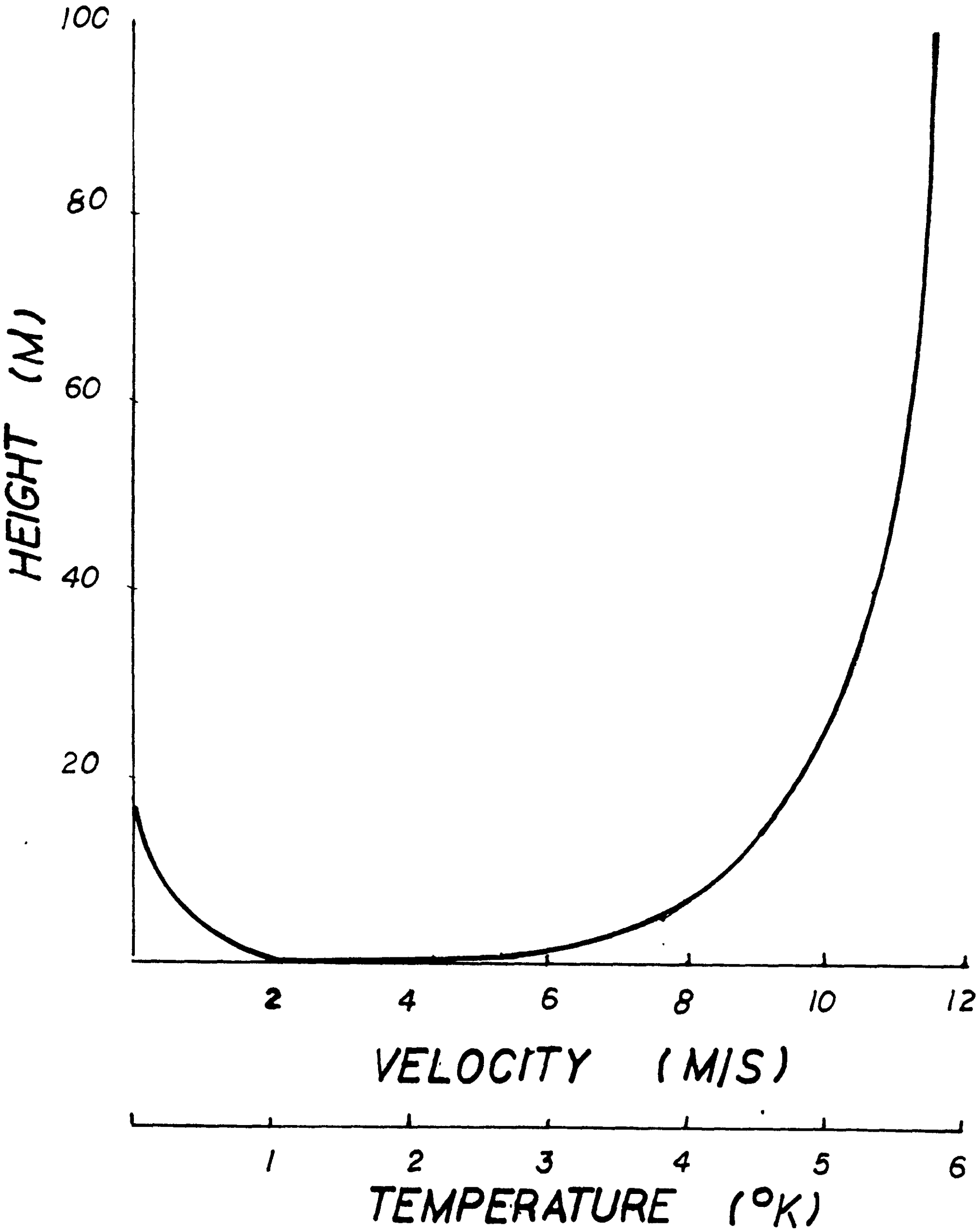


Figure 4.15

Mean Velocity and Mean Temperature
Profiles for the Neutral Atmosphere

Figure 4.16

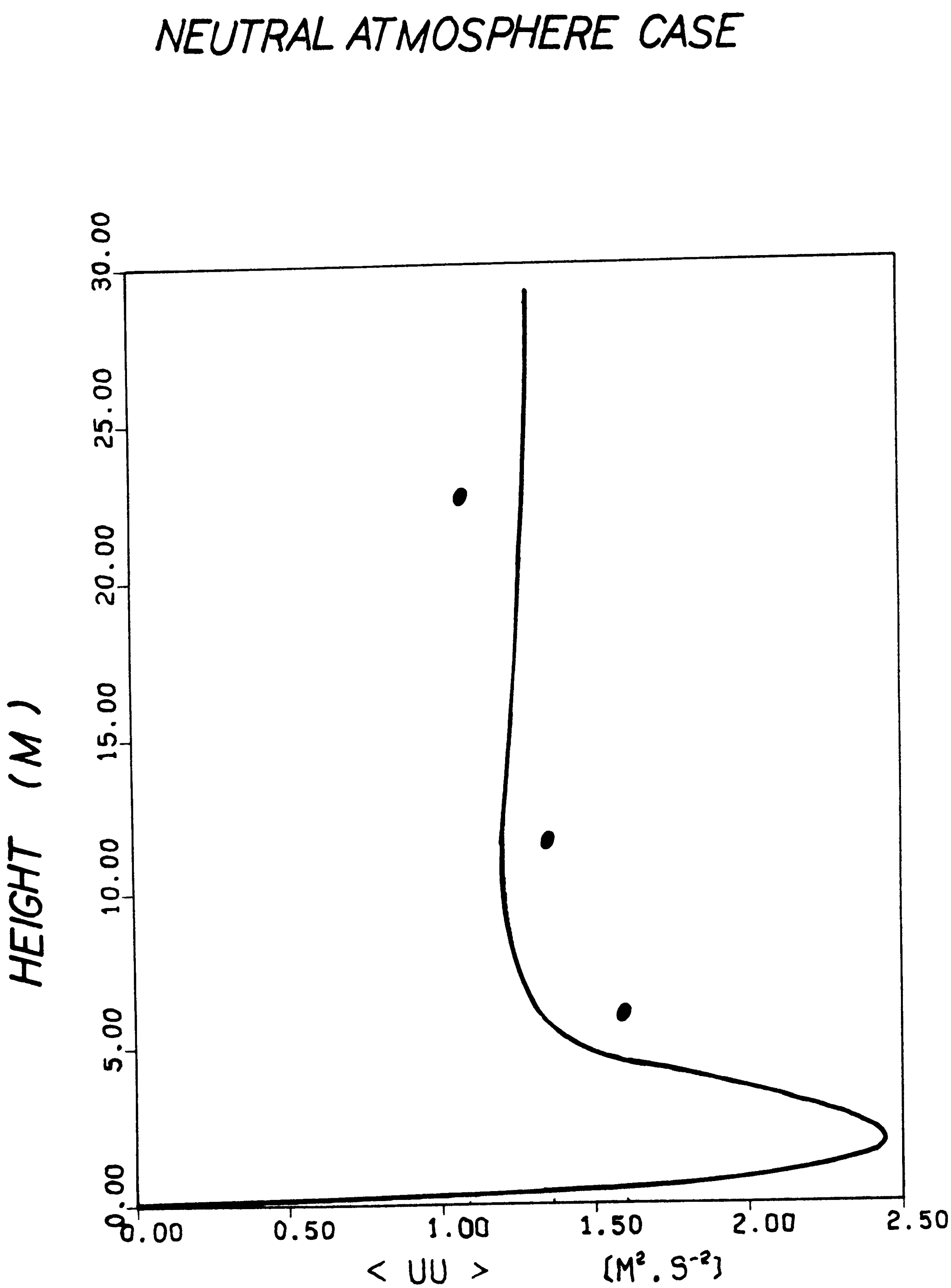

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.50
1.00
1.50
2.00
2.50
< UU > [M^2. S^{-2}]

Figure 4.17

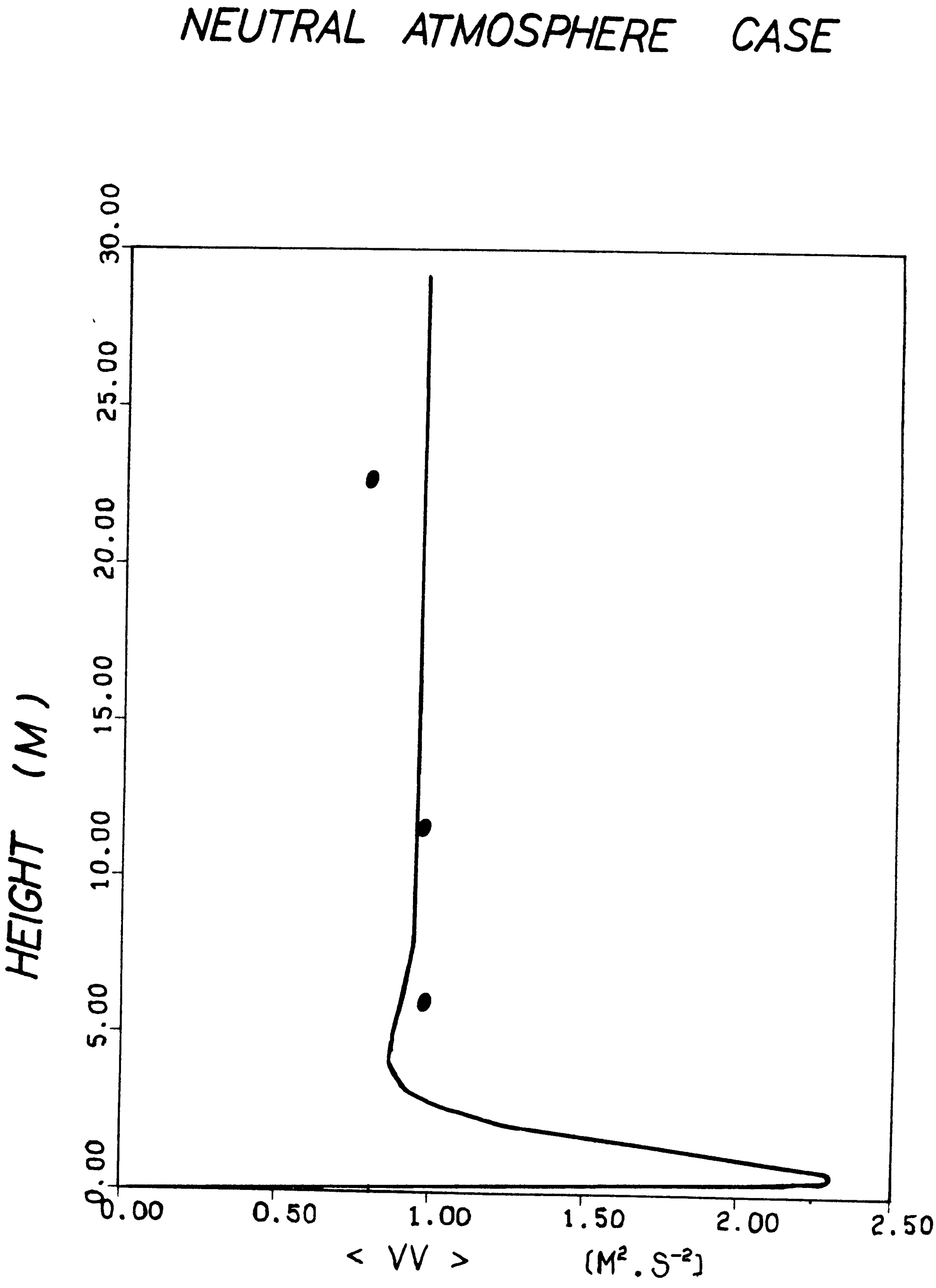

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
< VV > (M².S⁻²)

Figure 4.18

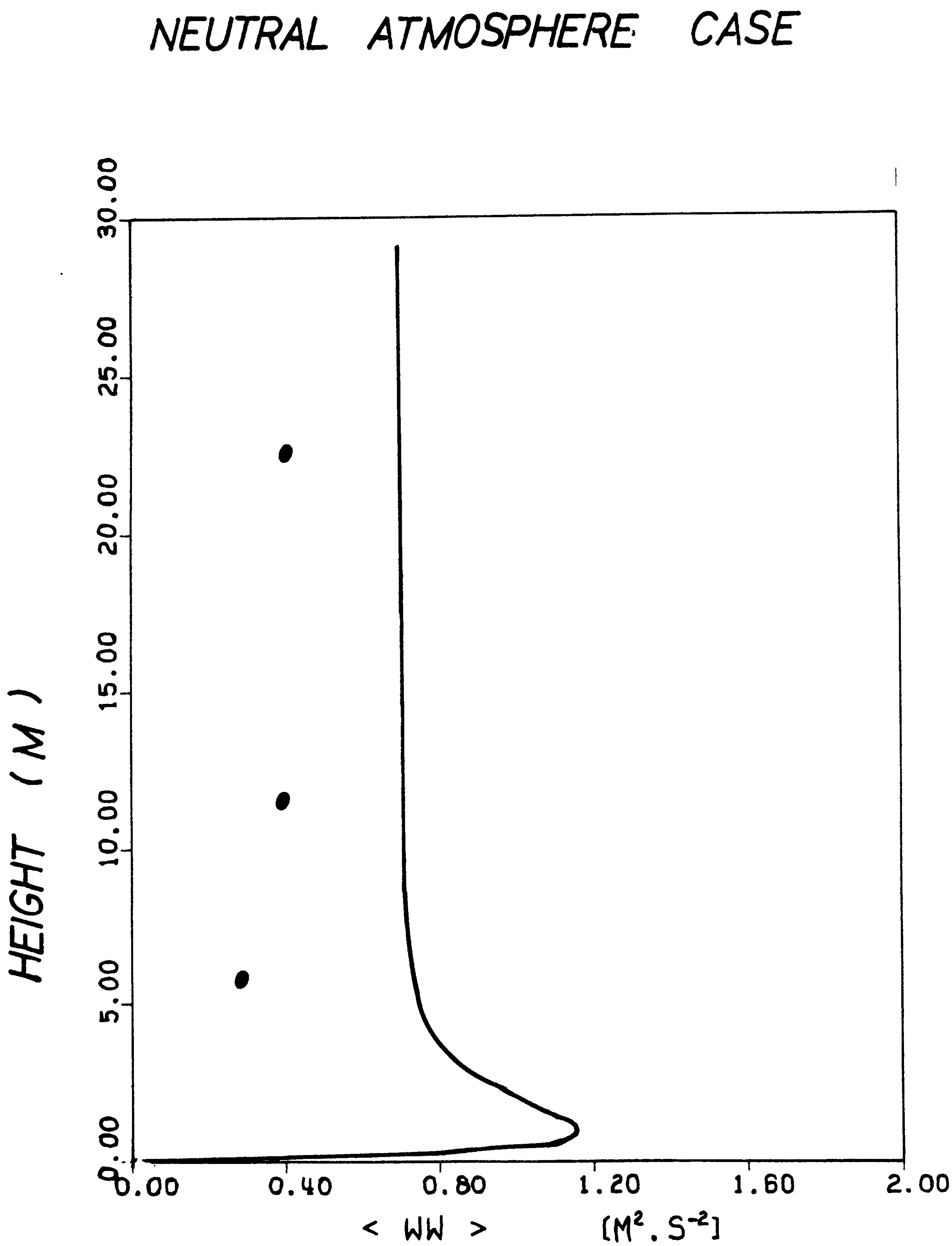

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.40
0.80
1.20
1.60
2.00
< WW > [M².S⁻²]

Figure 4.19

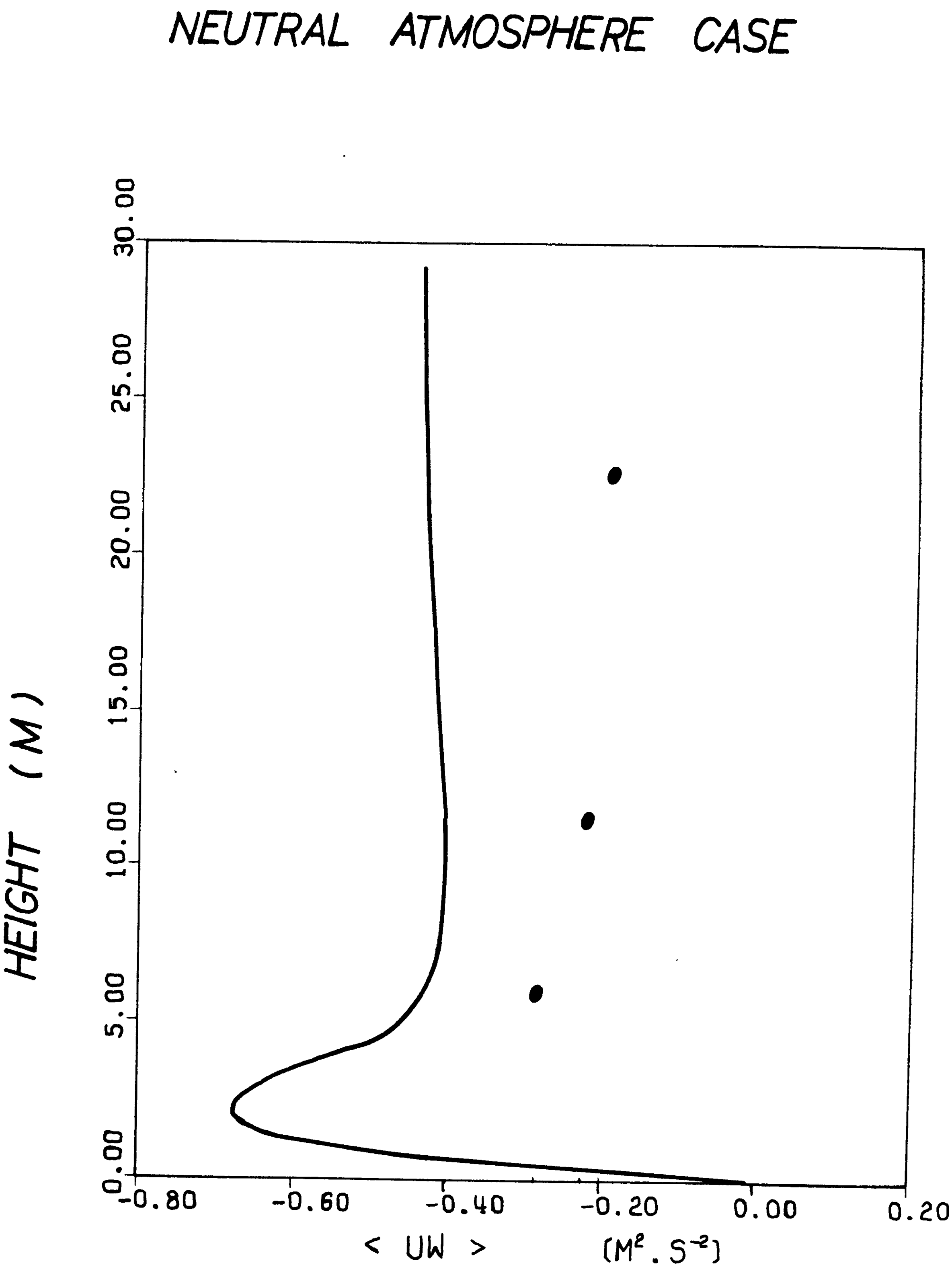

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
< UW > (M².S⁻²)

Figure 4.20

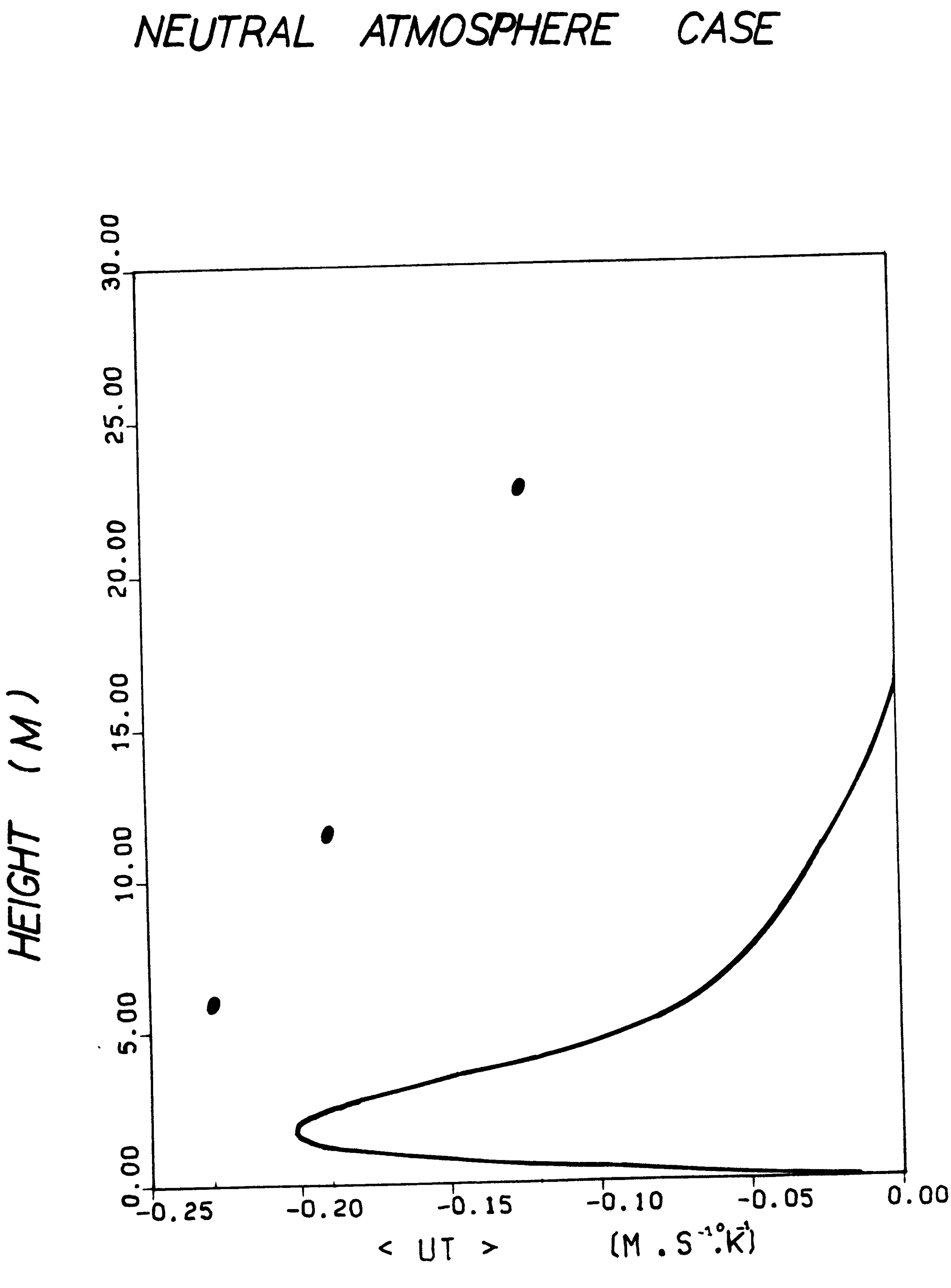

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
< UT > (M . S⁻¹ .°K⁻¹)

Figure 4.21

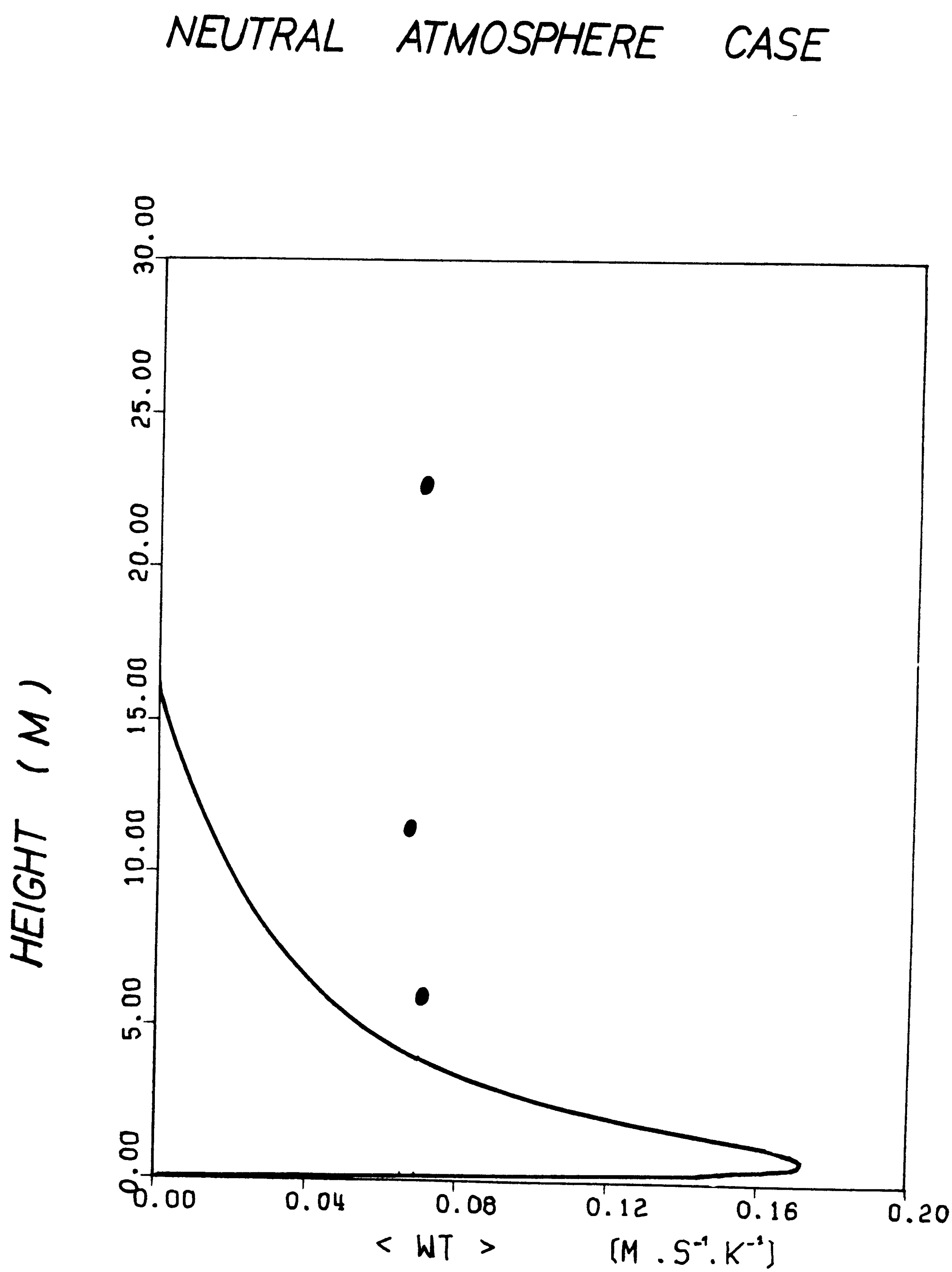

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.04
0.08
0.12
0.16
0.20
< WT > [M . S⁻¹. K⁻¹]

Figure 4.22

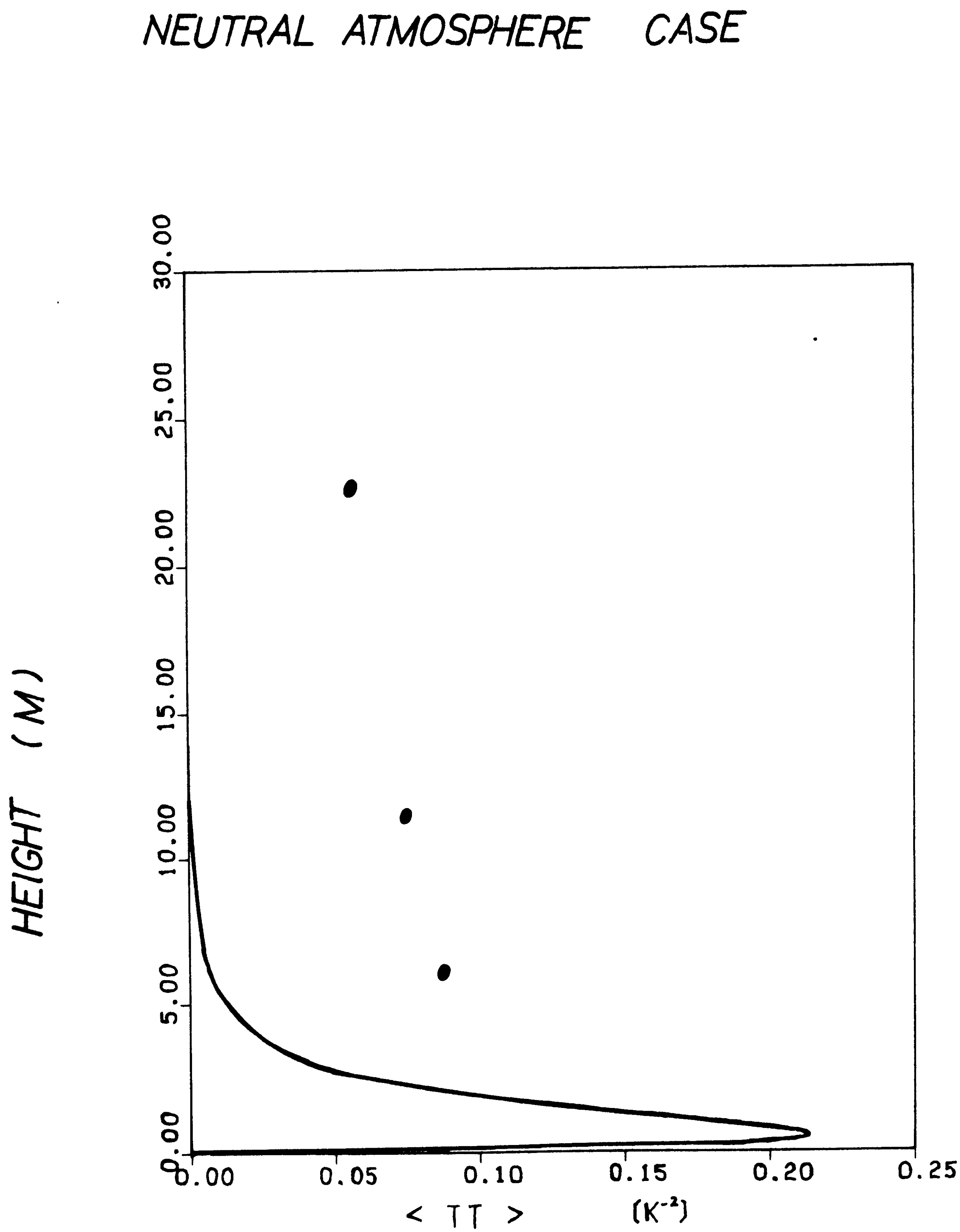

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
< TT >
(K⁻²)

Figure 4.23

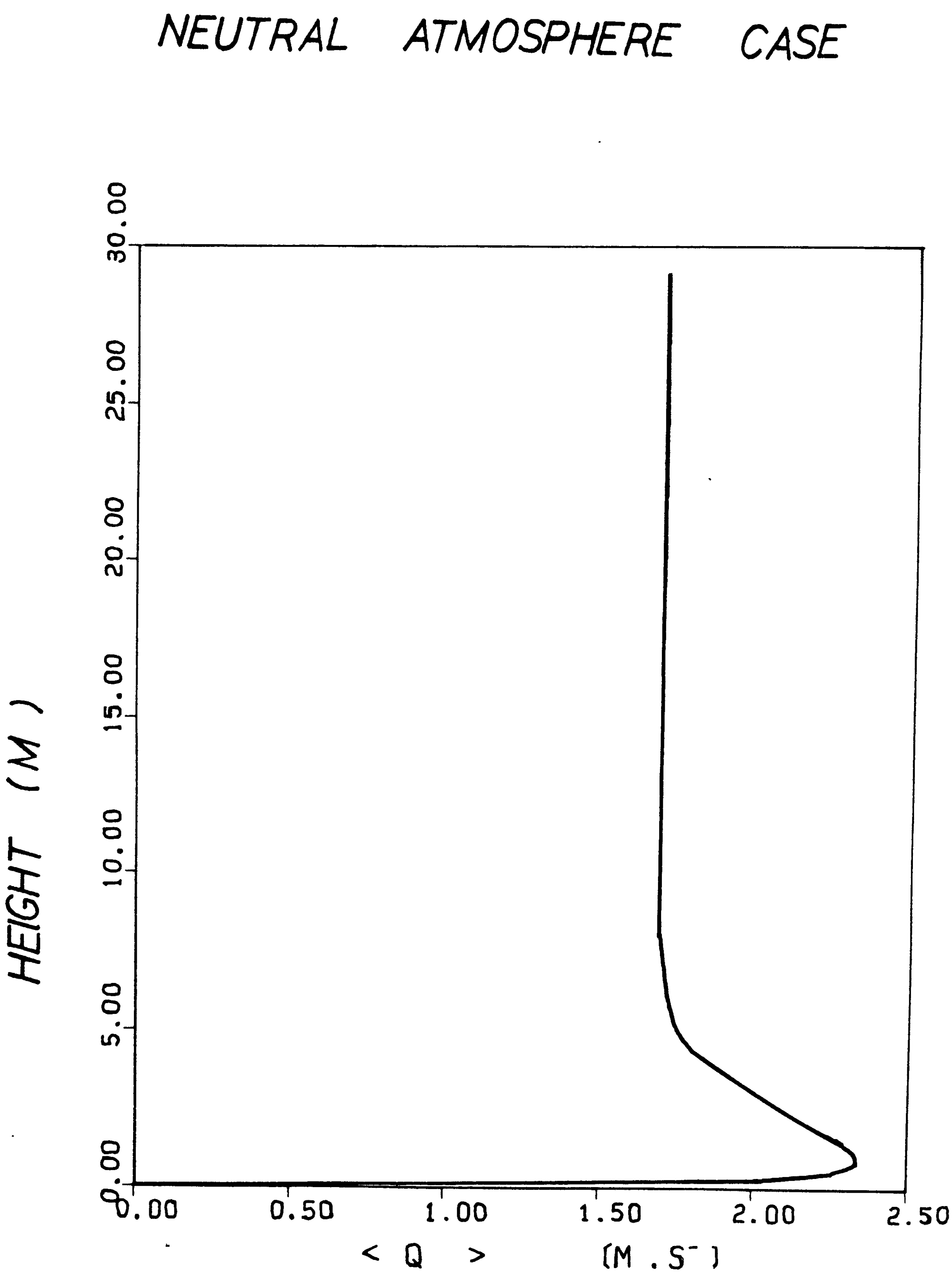

NEUTRAL ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
< Q > (M . S⁻)

Figure 4.24

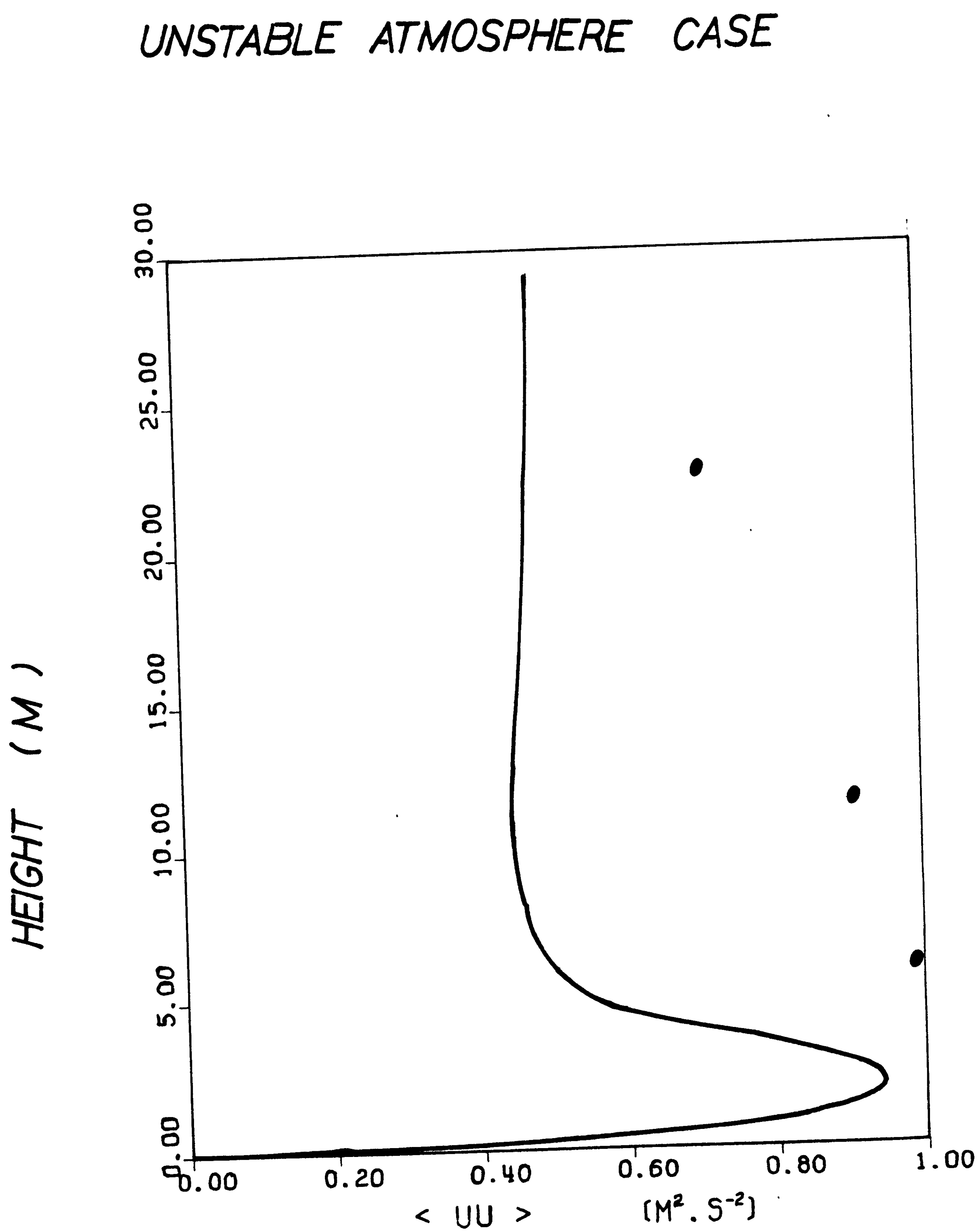

UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.20
0.40
0.60
0.80
1.00
< UU >
[M². S⁻²]

Figure 4.25

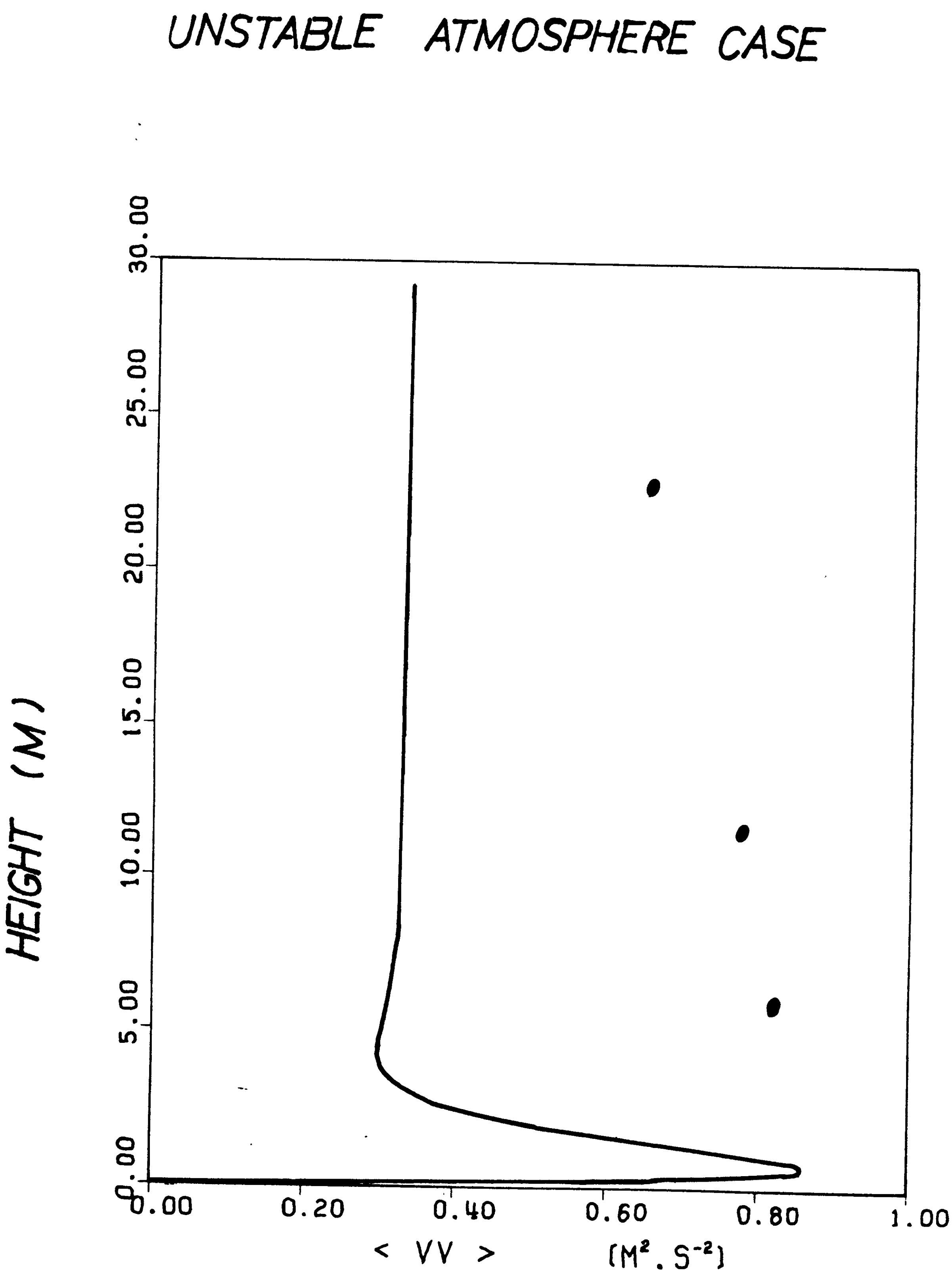

UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.20
0.40
0.60
0.80
1.00
< VV > [M². S⁻²]

Figure 4.26

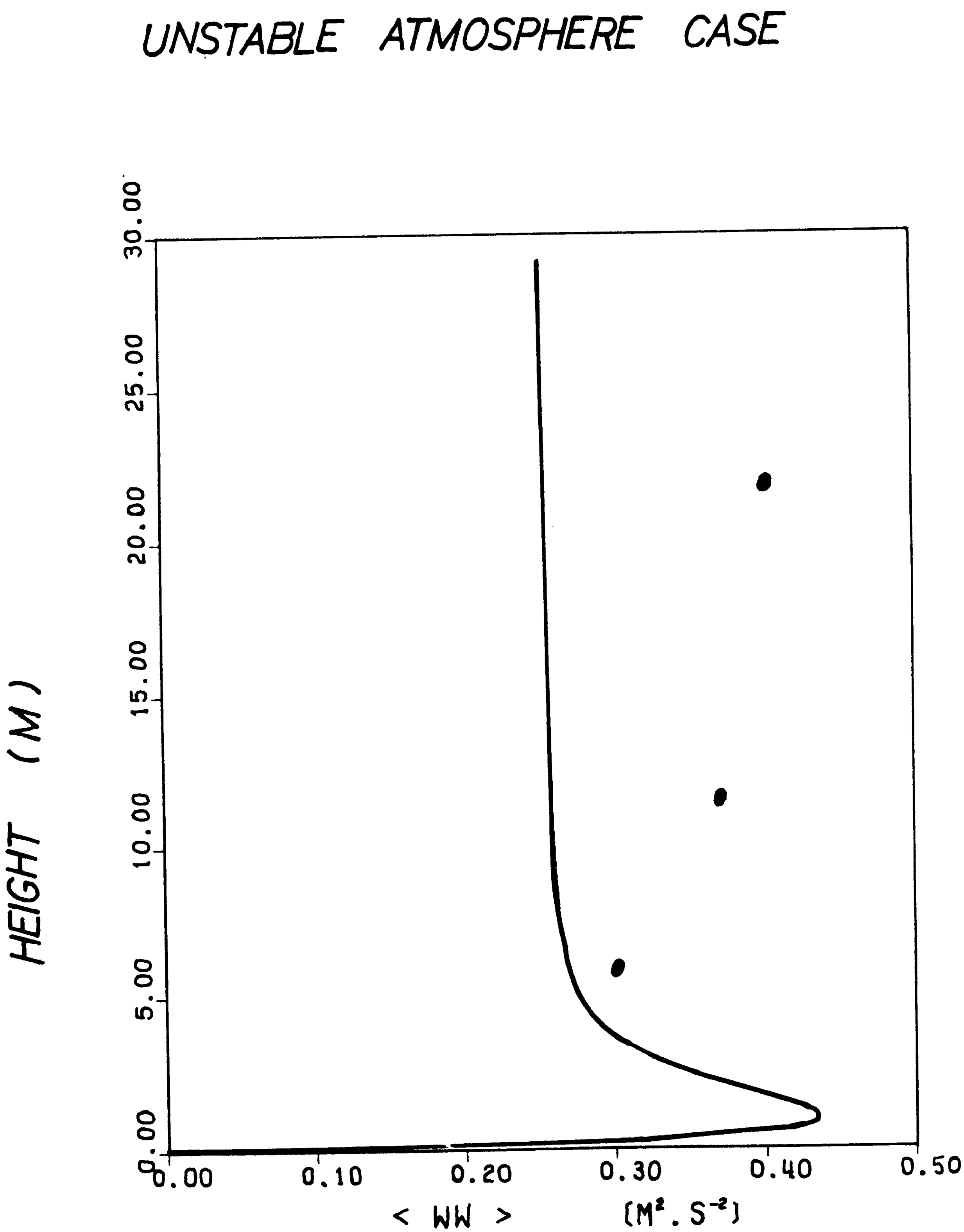

UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.10
0.20
0.30
0.40
0.50
< WW > [M².S⁻²]

Figure 4.27

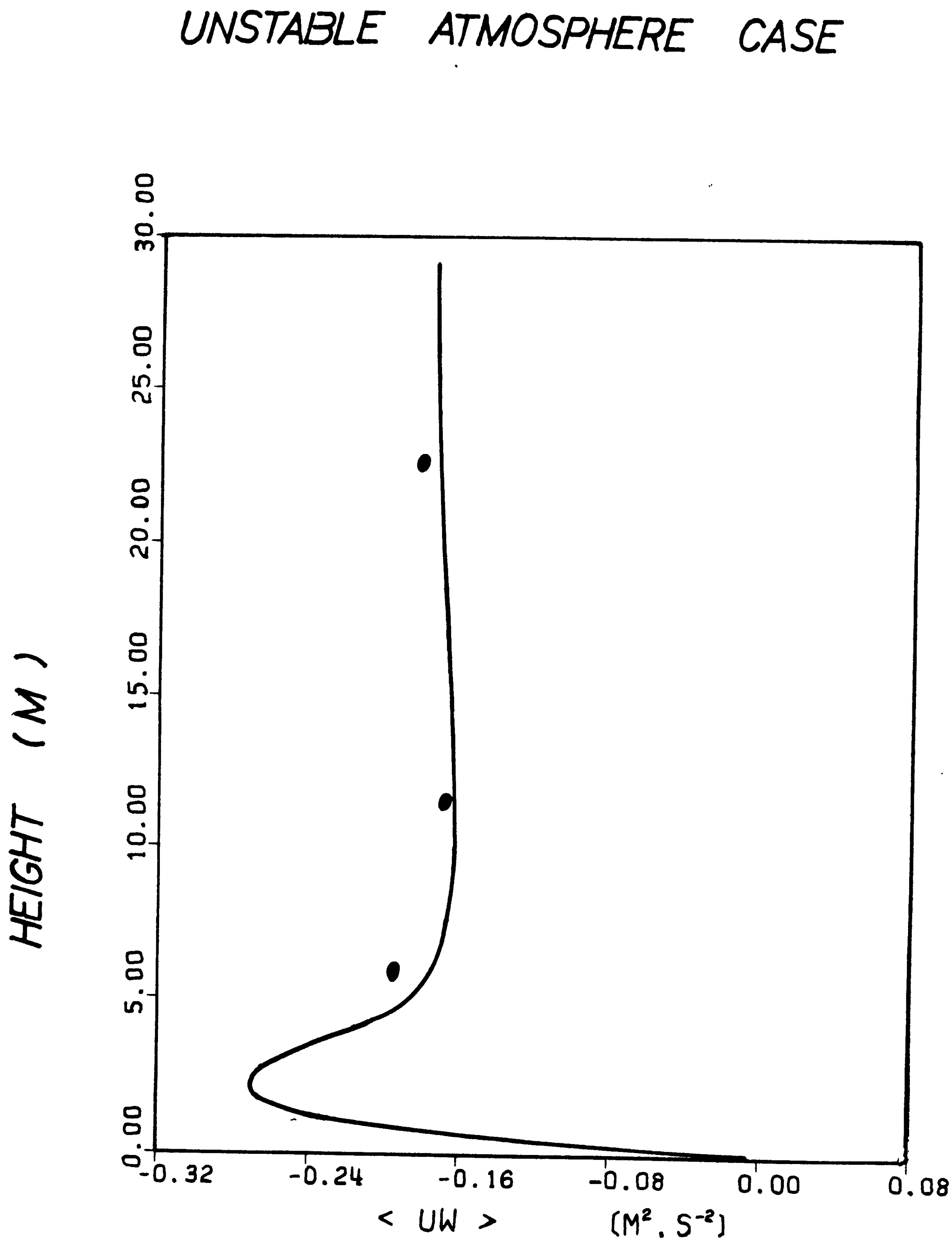

UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-0.32
-0.24
-0.16
-0.08
0.00
0.08
< UW > (M², S⁻²)

Figure 4.28

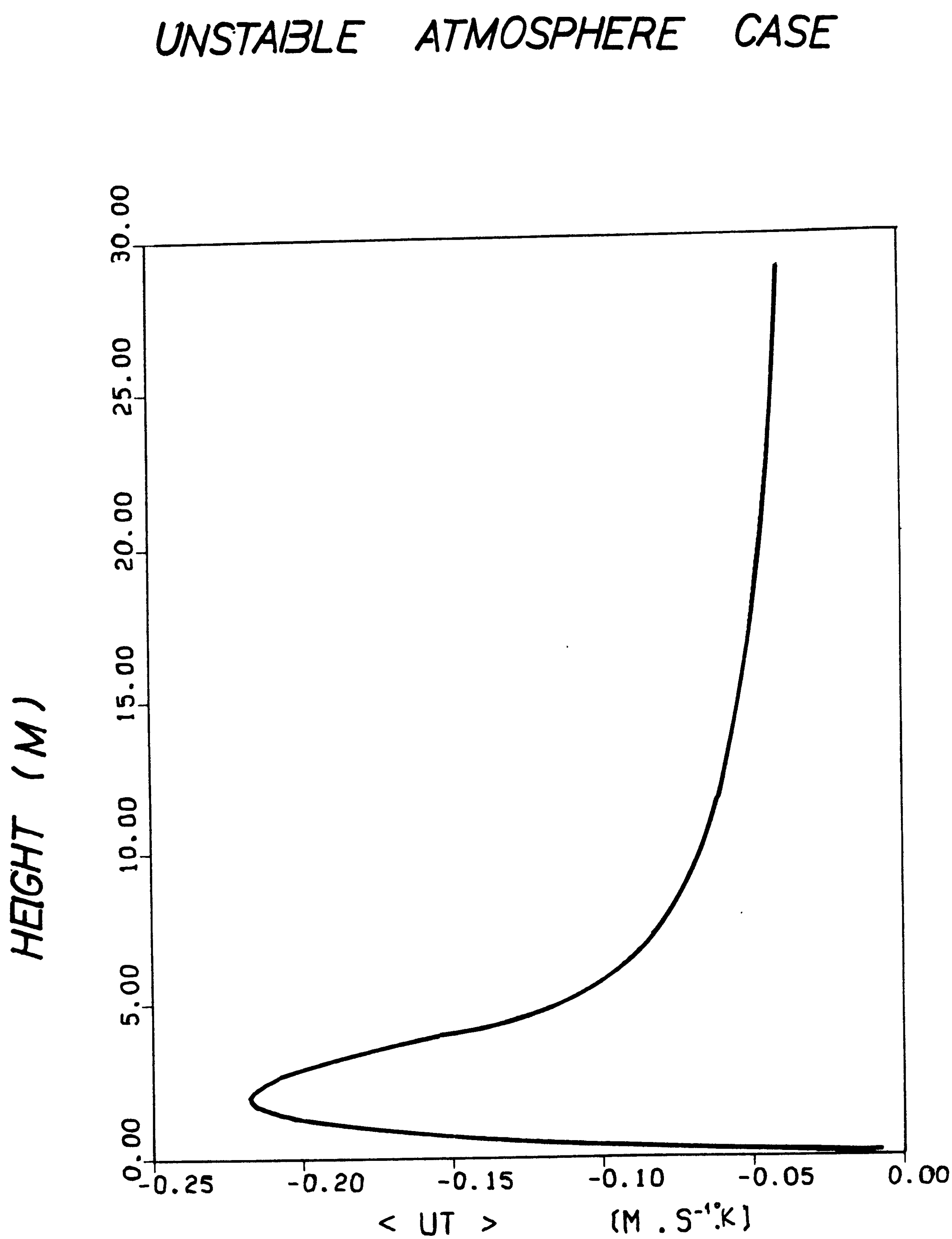

UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
< UT > (M . S-1.°K)

Figure 4.29

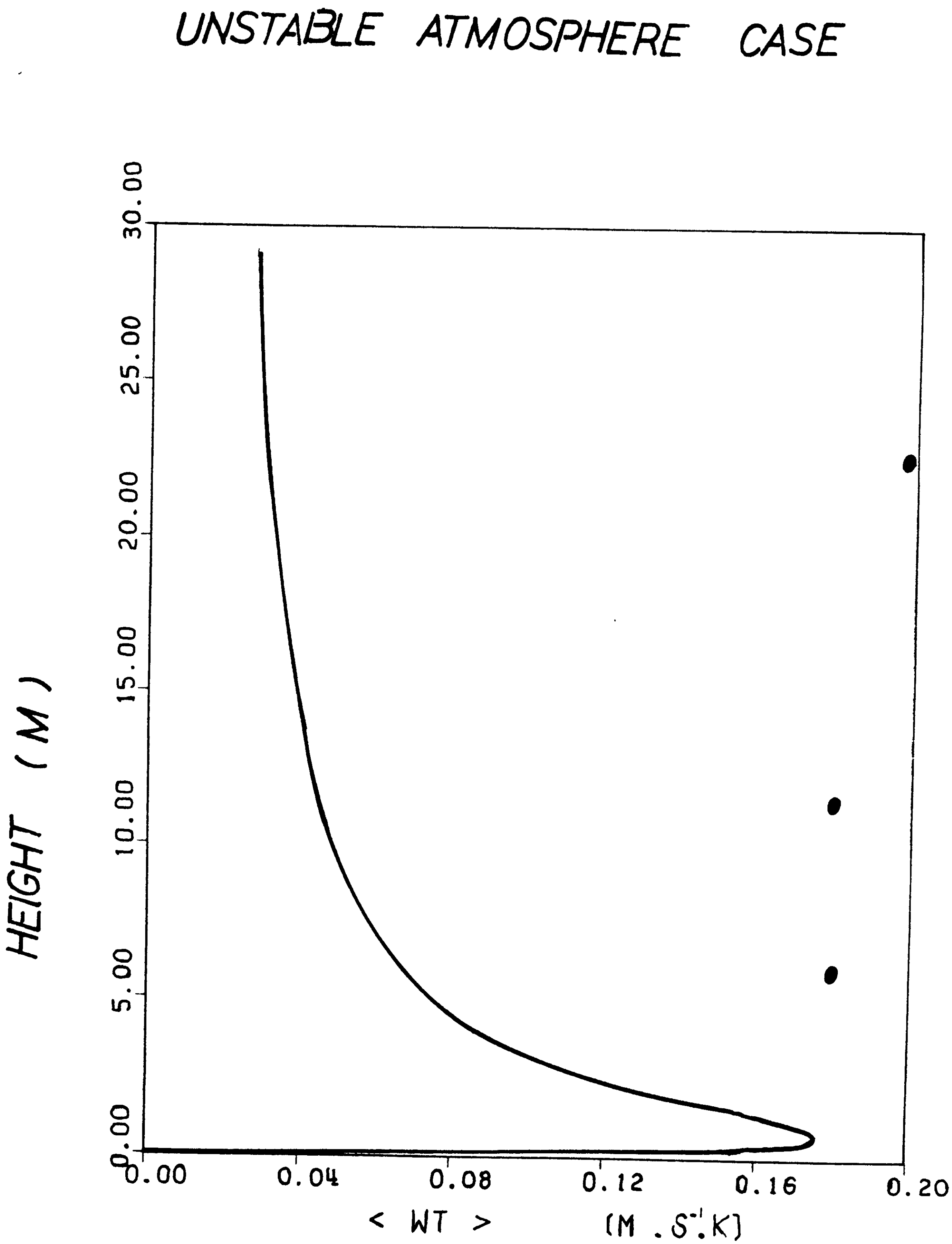

UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.04
0.08
0.12
0.16
0.20
< WT > (M . S⁻¹.K)

Figure 4.30

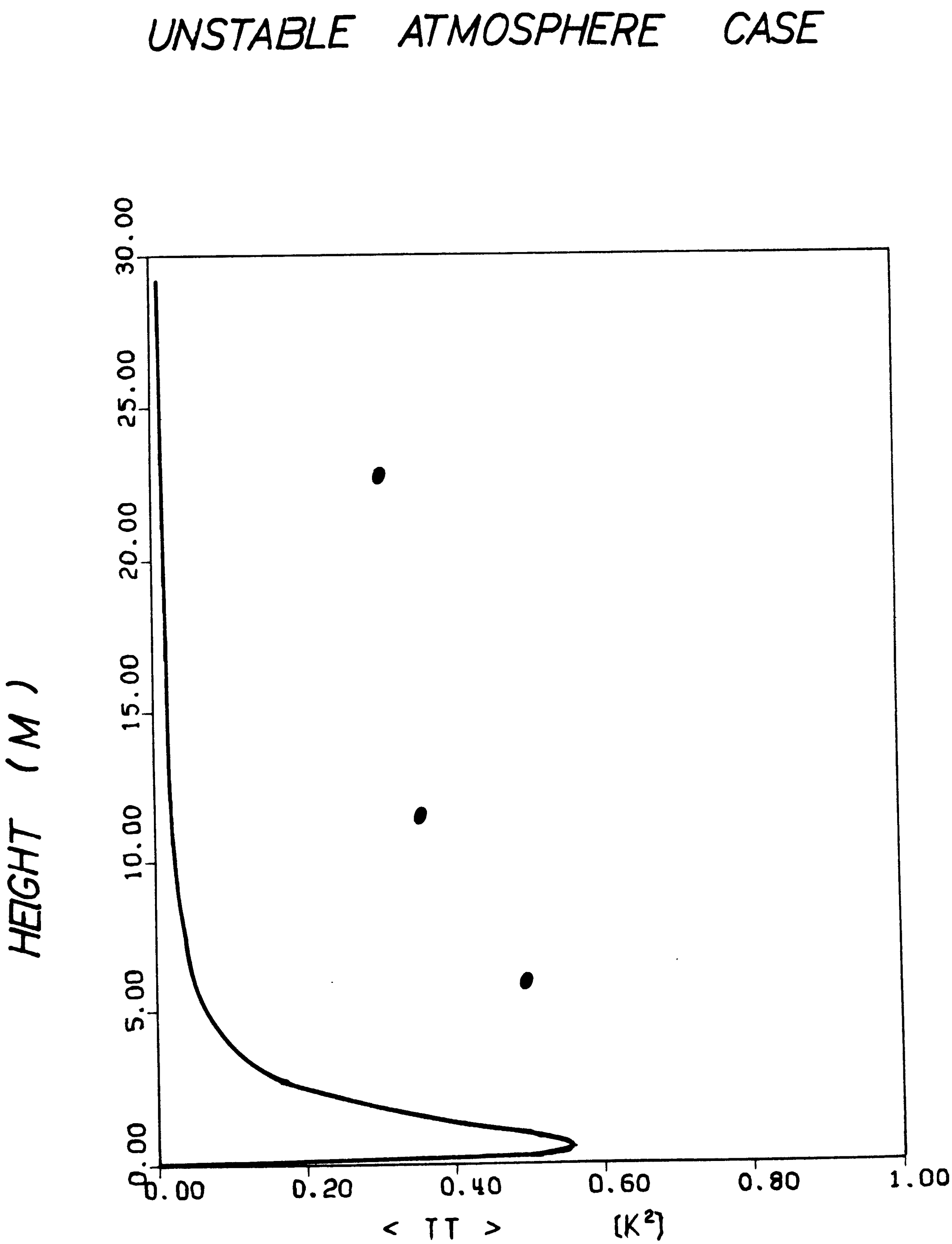
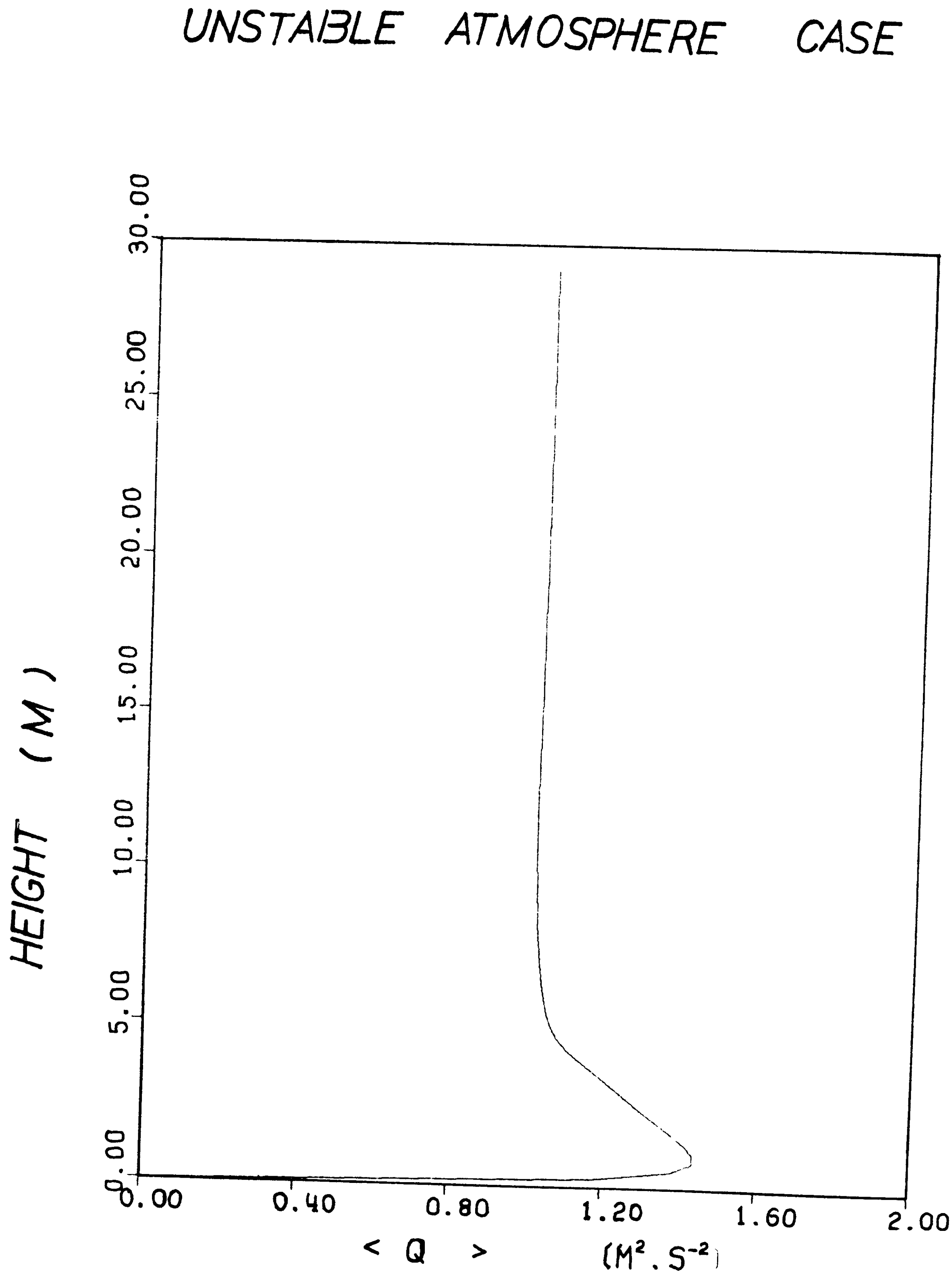

UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.20
0.40
0.60
0.80
1.00
< TT > [K²]

Figure 4.31



UNSTABLE ATMOSPHERE CASE
HEIGHT (M)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.40
0.80
1.20
1.60
2.00
< Q > (M².S⁻²)

5 RESULTS

5.1 Introduction

The discussion of the results of the computer plume simulations is divided into two sections corresponding to the two cases studied in this work.

The cases chosen for validation simulation are selected from a set of measurements at the TVA Paradise Steam Station. This set has been analyzed using integral entrainment models, by Policastro [3 with generally poor results. The two cases selected are for very buoyant plumes which remain visible for a long distance downward from point of release. From Figures 5.3a and 5.3b it is seen that most models fail to account properly for the rate of entrainment which results in an excess vertical momentum. The liquid water dynamics, which controls the dynamics of visibility is also poorly accounted for since most plumes dry out very quickly. Finally, the physical phenomena contained in entrainment models are only valid in the region of plume-dominated turbulence and cannot be transferred to the regime of atmospheric dominated turbulence. This results in the inability of these classes to models to simulate long plumes.

The complexity the atmosphere, in which the plumes are released represents a very good test of the model since it enables all parts of our model to be tested.

All these considerations and the abundance of the data represent an excellent incentive in choosing the February 3rd and February 10th visible plume as a validation test to the model.

The plumes extend far downwind, hence the atmospheric turbulence dominated plume region is large enough to allow adequate testing of the ability of the turbulence model to predict turbulent diffusion via atmospheric fluctuations. Such results are found in the sensitivity analysis in Section 5.5. Finally the two cases chosen are, because of the physical aspect of the plume, a good test for the moisture model developed in this work. These results are presented in Sections 5.3 and 5.4. The general nature of the solution and the available body of experimental results are described in Section 5.2.

5.2 General Nature of the Solutions and Data Base

5.2.1 General Nature of the Solutions

The general nature of all the computer solutions is discussed in this section. All of the simulations are performed using a 20-by-20 cell mesh, although the cell height and width vary between different simulations. The time step size is selected by the program at each time step, and is usually found in the range from one-tenth of a second to several seconds. The selection of a time step size is performed by the code, where it always chooses the smallest step size from a choice of a diffusion stability condition,

$$DT = \frac{TSTEP}{\max(\sigma)\ \frac{1}{Dy^2} + \frac{1}{Dz^2}} \quad ,$$

the courant condition,

$$\Delta T = TSTEP\ \frac{\min(Dx,Dz)}{\max(v,w)} \quad ,$$

or a simple rate of change condition

$$DT = \frac{.2\ \max(v,w)}{(\max(v,w) - \max(v_{old},w_{old}) + 10^{-6}} \quad ,$$

where TSTEP has usually a value between 0.01 and 0.3.

Full donor cell differencing of the advection terms is found to give the best answers in the simulations. Less than full donor cell differencing produces noticeable nonlinear instabilities in the flow. A simple plume development is found in Appendix C. Figure 5.1 explains the mesh cell quantities displayed in the figures.

5.2.2 Data Base

The data base used to validate the visible plume model, and the data treatment are described in this paragraph.

Data collected during the 1973 field studies at Paradise Steam Plant [60] have been made available to this work by the Tennessee Valley Authority (TVA). The main objective of the experimental work has been to provide observations on the trajectory and growth of the visible (condensed) portion of the plumes from natural-draft cooling towers. In addition to the plume observations the measurements extended to the acquisition of the plant operating conditions, measurement inside and at the base of the cooling towers, and measurement of ambient air parameters. The Paradise Steam Plant, a coal-fired power plant operated by the Tennessee Valley Authority, has two 704 MW units with two 183 m stacks and one 1150 MW unit with a 244 m stack. The plant has three hyperbolic natural-draft, evaporative, counterflow cooling towers. The towers are 133 m in height with base diameters of 98 m and top diameters of 62 m.

5.2.2.1 Ambient Air Data

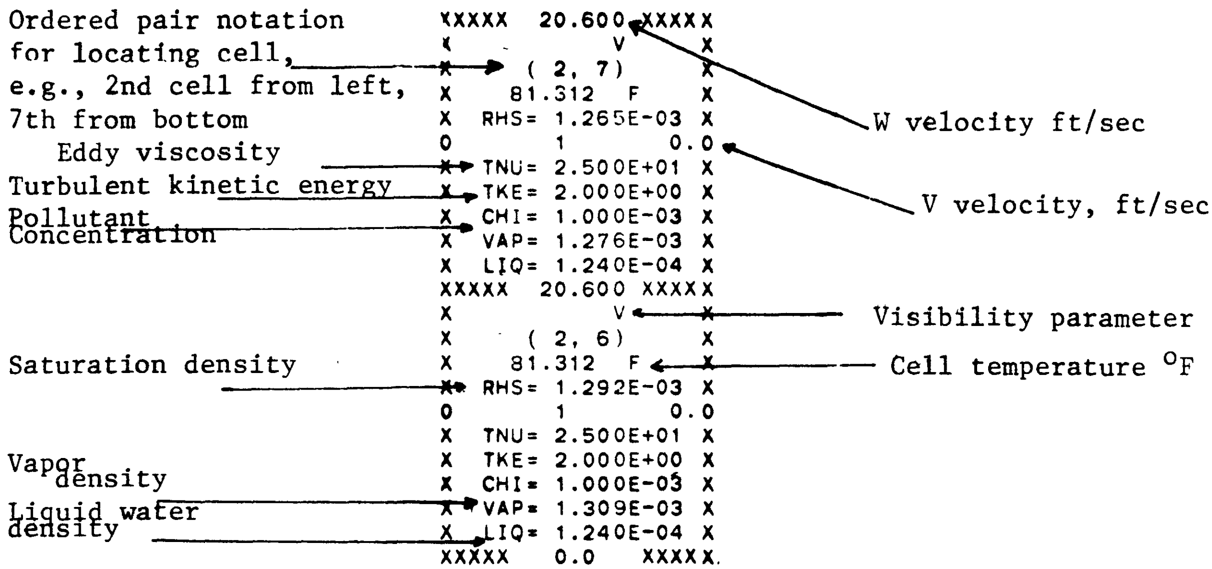
The dry-bulb and dew point temperature profiles of ambient air were obtained from an instrumented Bell model 47J2 helicopter. The helicopter flight plan consisted of ascending and descending spirals upwind of the cooling towers with a constant 21 m/sec forward speed. The profiles were flown continuously throughout the plume photographic period. The helicopter elevation was also recorded.

The wind speed and direction profiles were obtained by Pibal releases continuously during the period when the plume was being photographed.

5.2.2.3 Cooling Tower Source Data

Inlet and outlet condenser water temperatures were measured directly at the cooling tower. The exiting air velocity and temperature at the top of the tower were calculated from measurements made above the drift eliminators in the tower.

The dry-bulb, wet-bulb and dew-point temperatures of the ambient air at the base of the towers were measured 1 m above the ground. The flow rate of the circulating cooling tower was estimated by monitoring the pressure drop across the circulating pump.



TNU is the eddy viscosity in ft^2/sec

TKE is the turbulence kinetic energy in ft^2/sec^2

CHI is the pollutant concentration in lbm/ft^3

VAP is the vapor density in lbm H_2O/ft^3

LIQ is the liquid water density in lbm H_2O/ft^3

RHS is the saturation density in lbm H_2O/ft^3

Figure 5.1

Key to Cellwise Quantities for Output (see Appendix C)

5.2.3 Initialization of the Initial Plume Release

Given the geometrical configuration of the mesh it is important to initialize adequately the plume cells. The measured cooling tower parameters at the tower exit are local quantities, whereas the initial plume cell quantities are volume averaged. With the knowledge of the initial trajectory of the plume, one sees that close to the tower exit very strong mixing occurs which considerably enhances the horizontal momentum of the plume. Hence, it is necessary to mix the plume with ambient air before starting the simulation. This step is performed by allowing homogeneous mixing of the tower effluent with ambient air in such a way as to conserve momentum energy and water content. The local quantities for the two plumes considered are given in Table 5.1. The following steps are then ca ried.

Momentum Conservation: assuming homogeneous mixing, one has the following momentum conservation relationships.

$$\dot{m}_A u_A = (\dot{m}_A + \dot{m}_T) u \quad , \text{ and}$$
$$\dot{m}_T v_T = (\dot{m}_A + \dot{m}_T) v \quad . \tag{5.1}$$

Therefore one obtains the result

$$\frac{v}{u} = \left(\frac{\dot{m}_T}{\dot{m}_A}\right) \frac{v_T}{u_A} \tag{5.2}$$

In equation (5.2) the ratio v/u is obtained from the knowledge of the slope (α) of the plume of the exit of the tower (see Fig. 5.2) where

	Updraft Velocity W_o(m/s)	Plume Exit Temp. °C	Average Ambient Temp. °C	Wind Speed at Tower Exit U_o(m/s)	Pressure at Tower Exit (mb)	W_o/U_o	Hot Water Temp °C	Cold Water °C
February 3rd Case	6.2	27.3	1.8	3.2	1000.7	1.94	33.5	23.6
February 10th Case	6.8	26.0	-2.4	3.0	1009.2	2.27	32.5	20.2

TABLE 5.1

LOCAL INPUT QUANTITIES FOR THE TWO PLUMES CONSIDERED

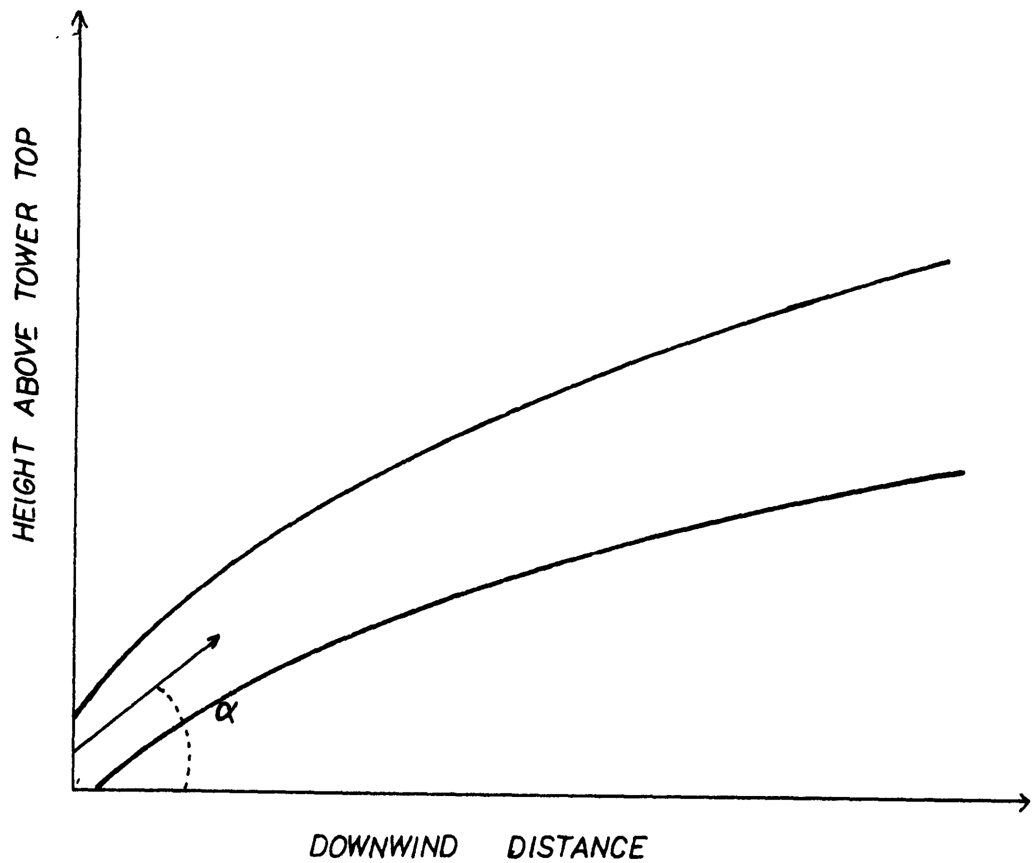


Figure 5.2

Initial Plume Trajectory

where ρ_T^v and ρ_A^v are the vapor densities at the tower exit and the ambient respectively. However from the momentum conservation one has the result

$$\dot{m}_T = \beta \dot{m}_A \tag{5.8}$$

or:

$$\rho_T V_T = \beta \rho_A V_A \quad .$$

Thus, one obtains the ratio γ as

$$\gamma = \frac{V_A}{V_T} = \beta \left(\frac{\rho_T}{\rho_A}\right)$$

Thus, Eq. (5.7) takes the form

$$\rho = \rho_T^v \frac{1}{1+\gamma} + \rho_A^v \frac{\gamma}{1+\gamma} \quad . \tag{5.9}$$

Also, from the conservation of momentum one has the result

$$\dot{m}_T = \beta \dot{m}_A$$

or:

$$\rho_T A_T V_T = \beta \rho_A H W V_A \quad ,$$

where V_T is the updraft velocity at the tower exit,

V_A is the wind velocity at the tower exit,

H is the mesh cell height, and

$$\tan(\alpha) = {}^{v}/_{u} \quad . \tag{5.3}$$

Thus one obtains the results

$$\beta = \frac{\dot{m}_T}{\dot{m}_A} = \frac{v}{u}\left(\frac{u_A}{v_T}\right) \tag{5.4}$$

and

$$u = \frac{u_A}{1+\beta} \quad , \quad v + \frac{\beta\ v_T}{1+\beta} \quad . \tag{5.5}$$

See Table 5.2 for the quantitative results.

Energy Conservation: assuming homogeneous mixing one obtains the result for conservation of energy

$$\dot{m}_T T_T + \dot{m}_A T_A = (\dot{m}_A + \dot{m}_T)\, T \quad , \text{ or}$$

$$T = \frac{\dot{m}_T T_T + \dot{m}_A T_A}{\dot{m}_A \div \dot{m}_T} = \frac{\beta T_T + T_A}{1+\beta} \quad . \tag{5.6}$$

Moisture Mass Conservation: similarly, mass conservation considerations lead to the result

$$\rho^v (V_A + V_T) = \rho_T^v V_T + \rho_A^v V_A$$

where V_A and V_T are the volume occupied by the moisture in one second of flow of ambient air and tower effluent respectively. Hence:

$$\rho = \rho_T^v \frac{V_T}{V_A} + \rho_A^v \frac{V_A}{V_T} \quad , \tag{5.7}$$

	Plume Initial Temp. °F	Updraft Velocity (ft/sec)	Vapor Density (lbm/ft^3)	Liquid Water Density (lb/ft^3)	Cell Height (ft)	Cell Width (ft)
February 3rd Case	53.852	6.6	5.88 10^{-4}	1.84 10^{-4}	165	165
February 10th Case	69.065	7.8	9.13 10^{-4}	3.08 10^{-4}	247	130

TABLE 5.2

Input Quantities for the Two Plumes
Considered after Intial Mixing

W is the mesh cell width.

Therefore

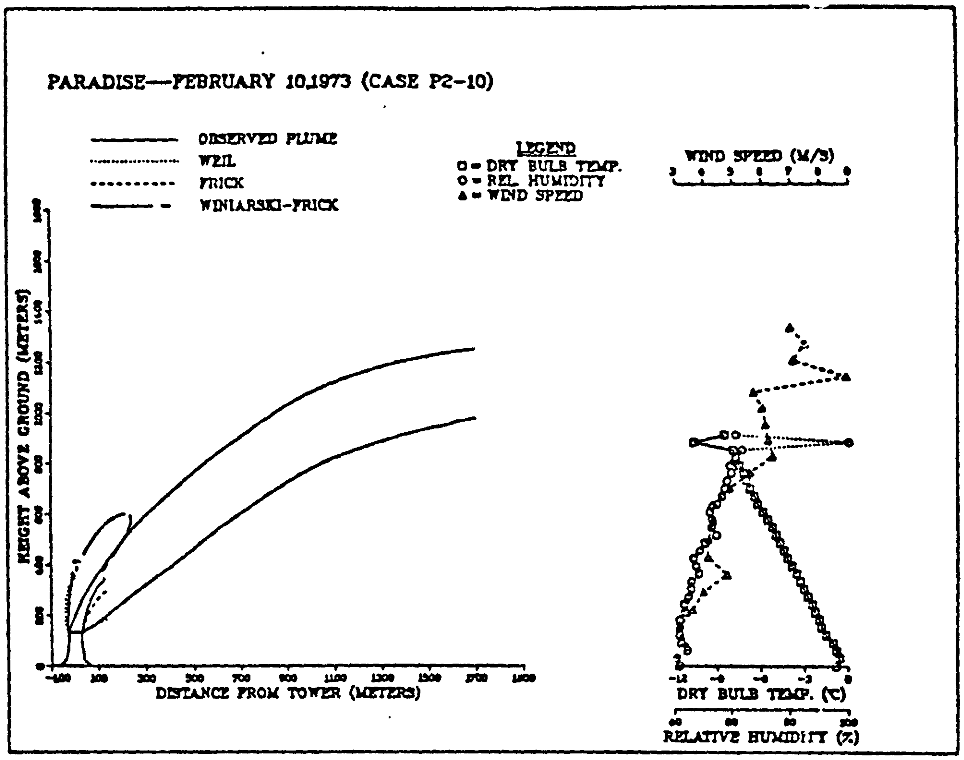
$$H.W = \left(\frac{\rho_T}{\rho_A}\right)\left(\frac{V_T}{V_A}\right)\left(\frac{1}{\beta}\right) \tag{5.10}$$

In order to be consistent with the conservation laws, one must keep the product H.W constant and equal to the quantity in Eq. (5.10). For the quantitative results see Table 5.2.

5.3 The Paradise Plant February 3rd Visible Plume

To test the model in its generality, it is imperative to select validation cases which involve all of the physical phenomena that the model is capable of simulating. Most of the field plume measurements are too limited to provide a good test of the model (the plume dries out rapidly), and some are also too easy to analyze (simple stability cases). The motivation behind the choice of the Paradise plumes lies in the complexity of the atmosphere in which they are released, and the long life of the visible plumes. Therefore they represent an excellent test of the potential of the model addressed in this work.

The experimental results for this plume are shown in Fig. 5.4. The data show the prevailing wind speed, potential temperature and water vapor profiles. An inversion was observed at an elevation of approximately 850 m — near the height at which the plume was observed



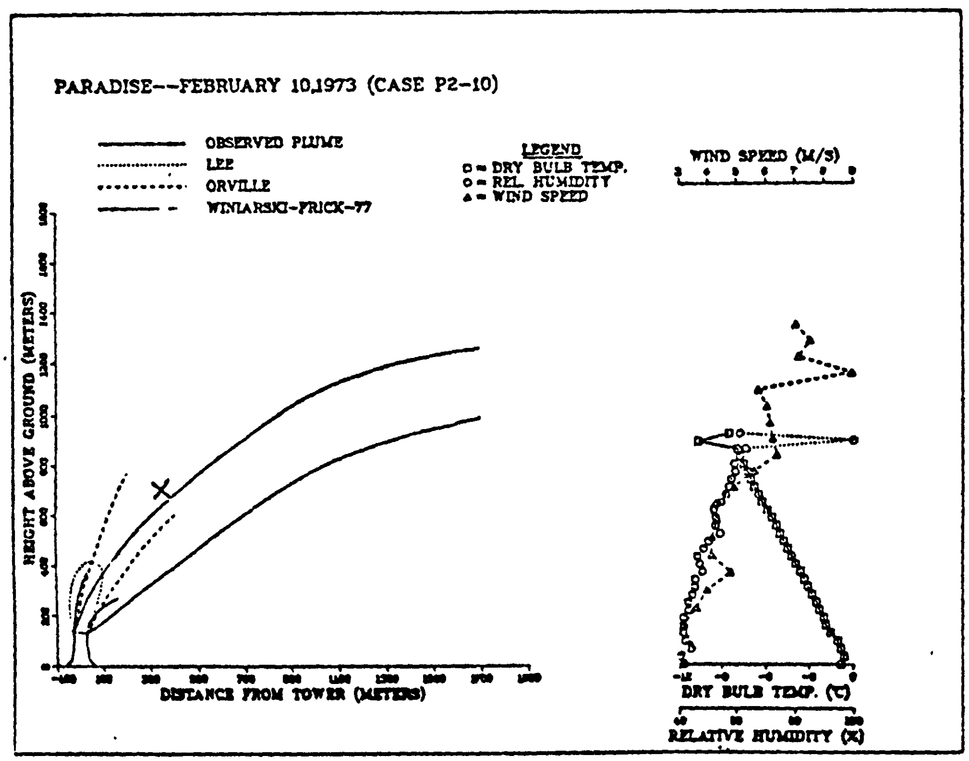
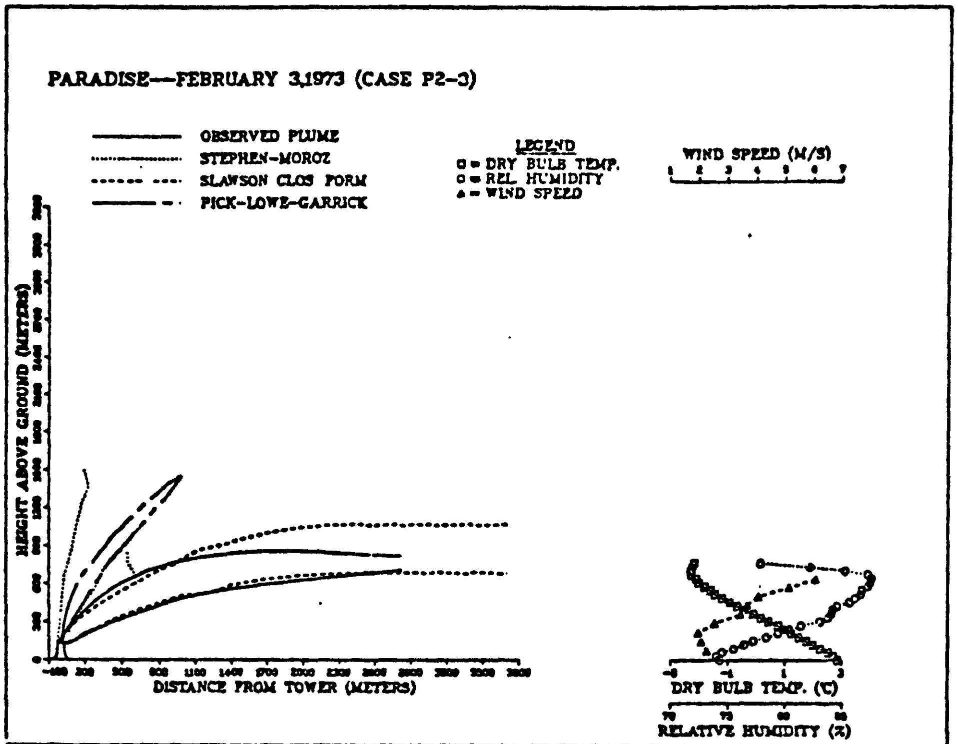


FIGURE 5.3a

Comparison Between the Measured Plume With the Result of Conventional Model (Entrainment). (With the permission of the author, Dr. Policastro, Argonne National Laboratory, [35]).



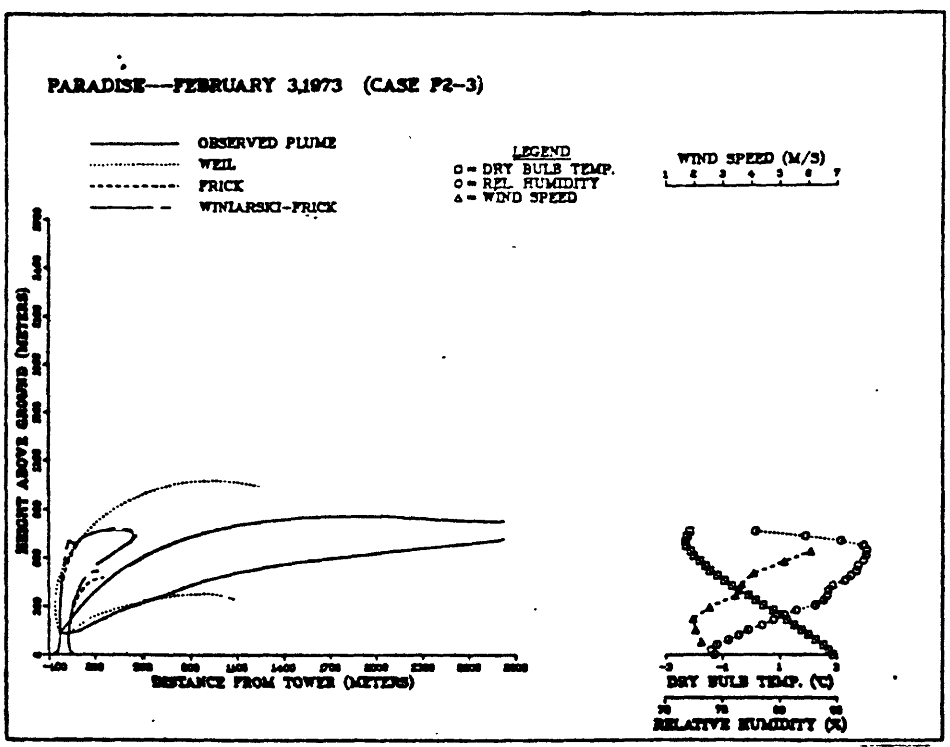


FIGURE 5.3b
Comparison Between the Measured Plume With the Result of Conventional Model (Entrainment). (With the permission of the author, Dr. Policastro, Argonne National Laboratory, [35]).

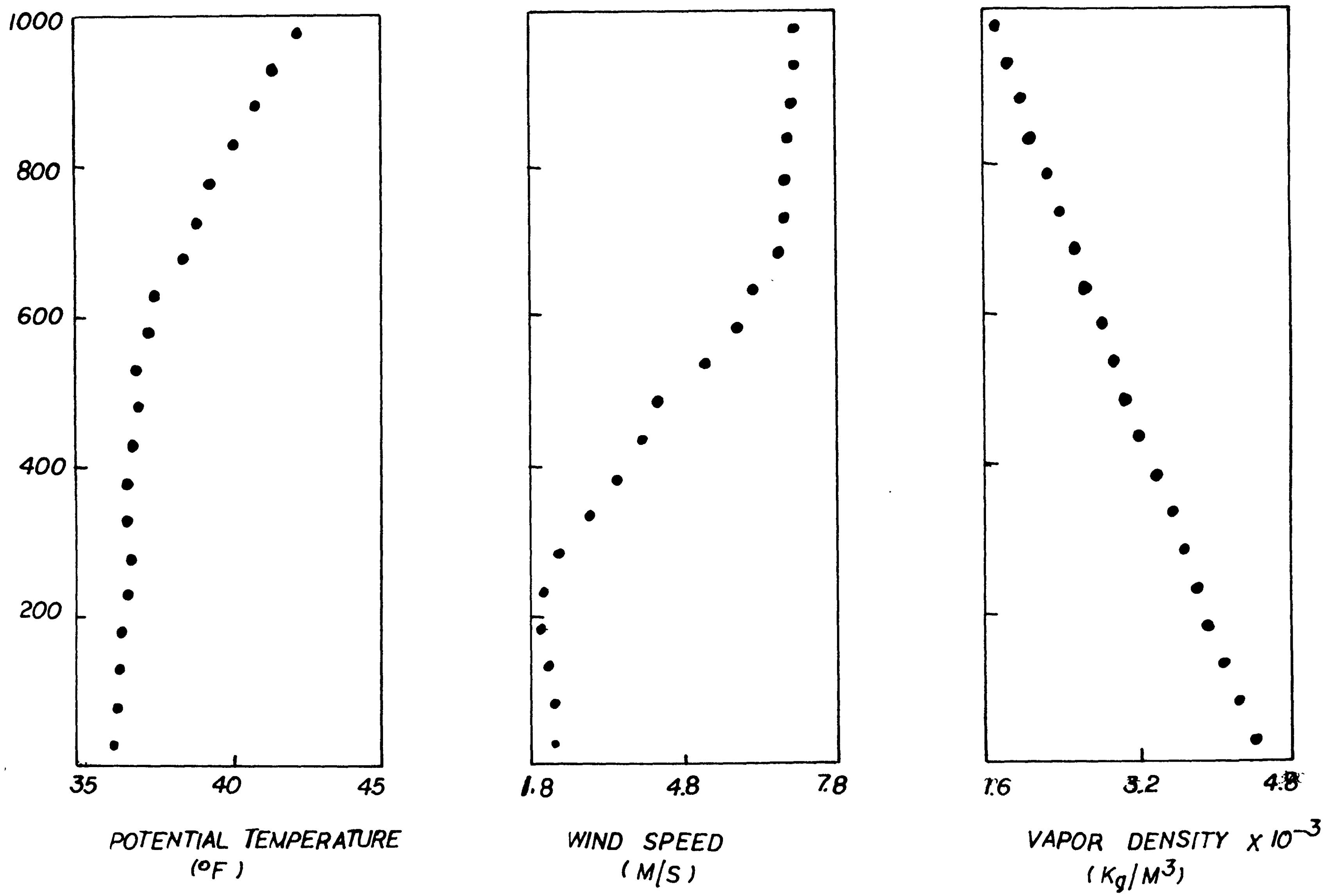


Figure 5.4
February 3rd

Measured Input Profile at the Paradise Site to level off. Also the wind speed above the inversion was significantly stronger than that below the inversion. The strong inversion at the top of the measured profile, blocks further plume rise. At the inversion elevation a moisture instability of very low saturation deficit maintains the plume visibility over a long downwind distance, since considerable atmospheric diffusion is needed to evaporate the plume liquid water.

The turning of the wind with height is ignored in the computer simulation, but the wind speed and potential temperature values are input directly onto the computer mesh. Turbulence values are calculated by the turbulence model and are shown in Figs. 5.5 - 5.12. The effect of the inversion layer results in suppressed levels of turbulence as can be seen from Figs. 5.8 and 5.12. Within the inversion layer the turbulence kinetic energy and turbulence kinematic viscosity decrease to very small values (10^{-2} ft^2/sec, 10^{-1} ft^2/sec^2) due to the strong stable lapse rate of the atmosphere above the inversion.

The liquid water content at the exit of the cooling tower of the plume is obtained from the Dibelius-Ederhoff correlation described in Chapter 2. Because of the relatively cold ambient air conditions the amount of liquid water is small compared to the amount of vapor. A value of 1.24 10^{-4} lbm/ft^3 of liquid water is found at the exit of the tower. After proper mixing with the ambient environment, the temperature of the mixed parcel decreases, therefore decreasing also

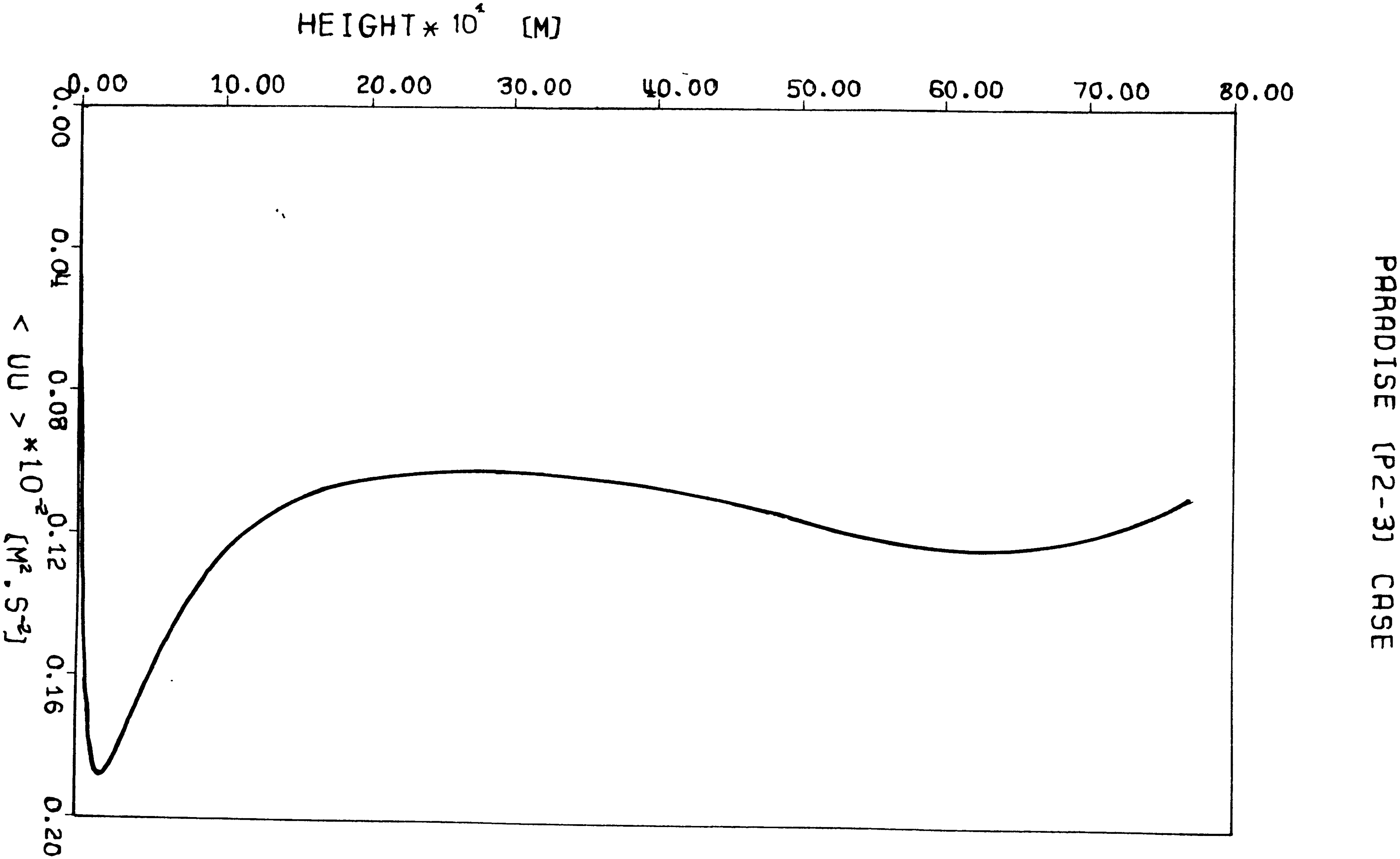

HEIGHT * 10 [M]
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
0.04
0.08
0.12
0.16
0.20
< UU > *10 [M², S⁻²]
PARADISE [P2-3] CASE

Figure 5.5

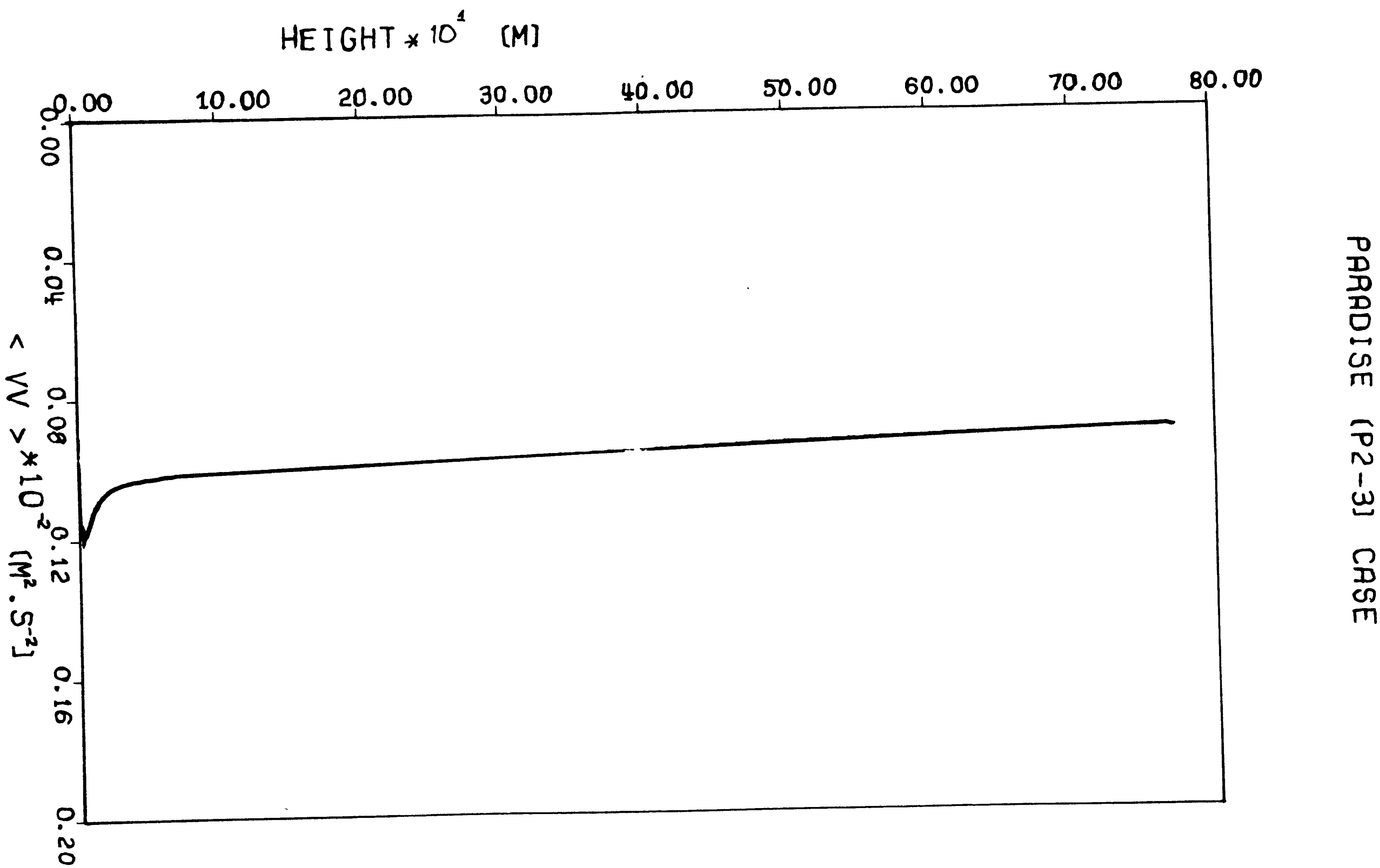

PARADISE (P2-3) CASE
HEIGHT * 10^1 (M)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
< VV >*10^-2 (M^2.S^-2)
0.00
0.04
0.08
0.12
0.16
0.20

Figure 5.6

PARADISE (P2-3) CASE

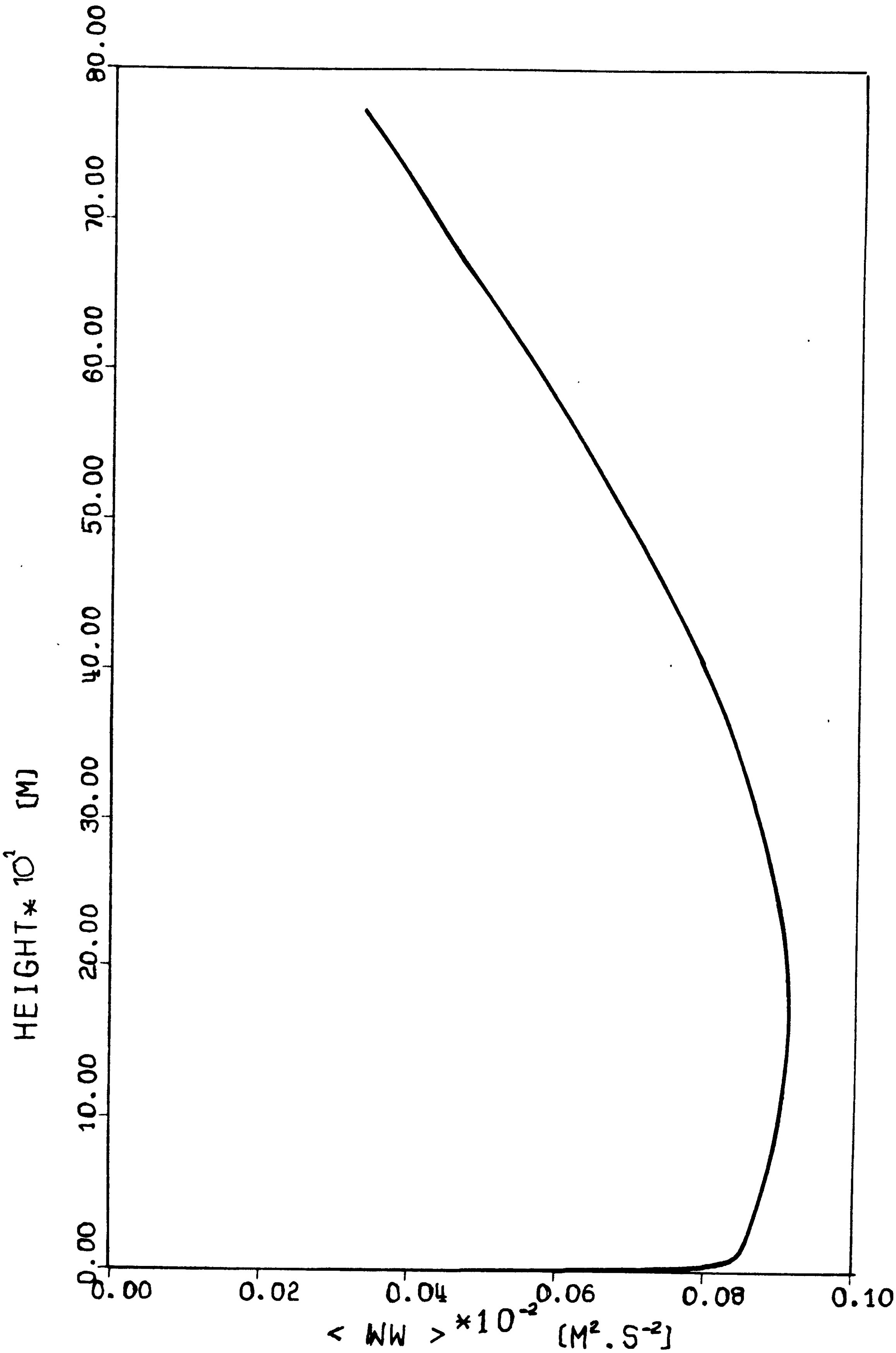


Figure 5.7

PARADISE (P2-3) CASE

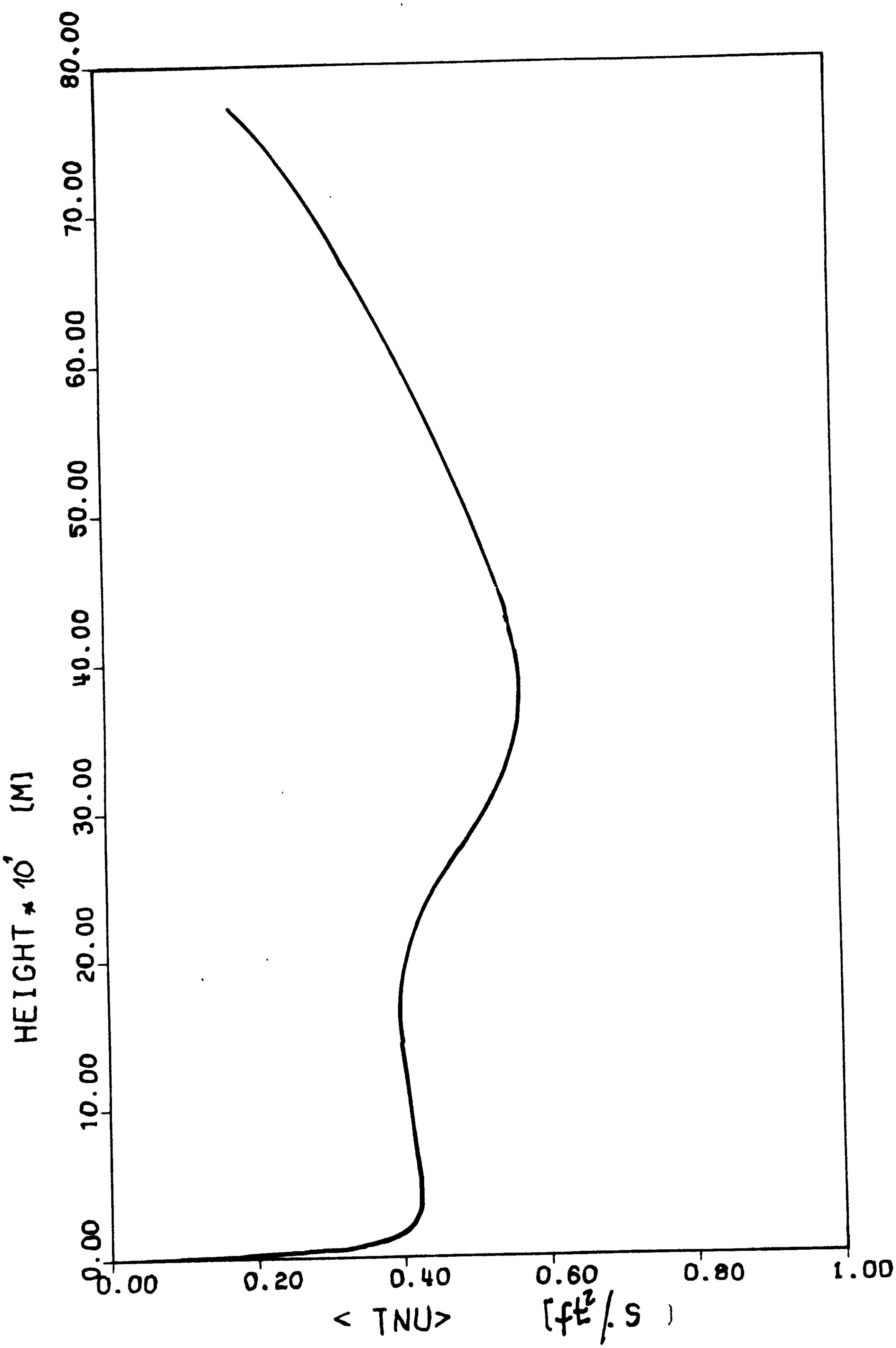
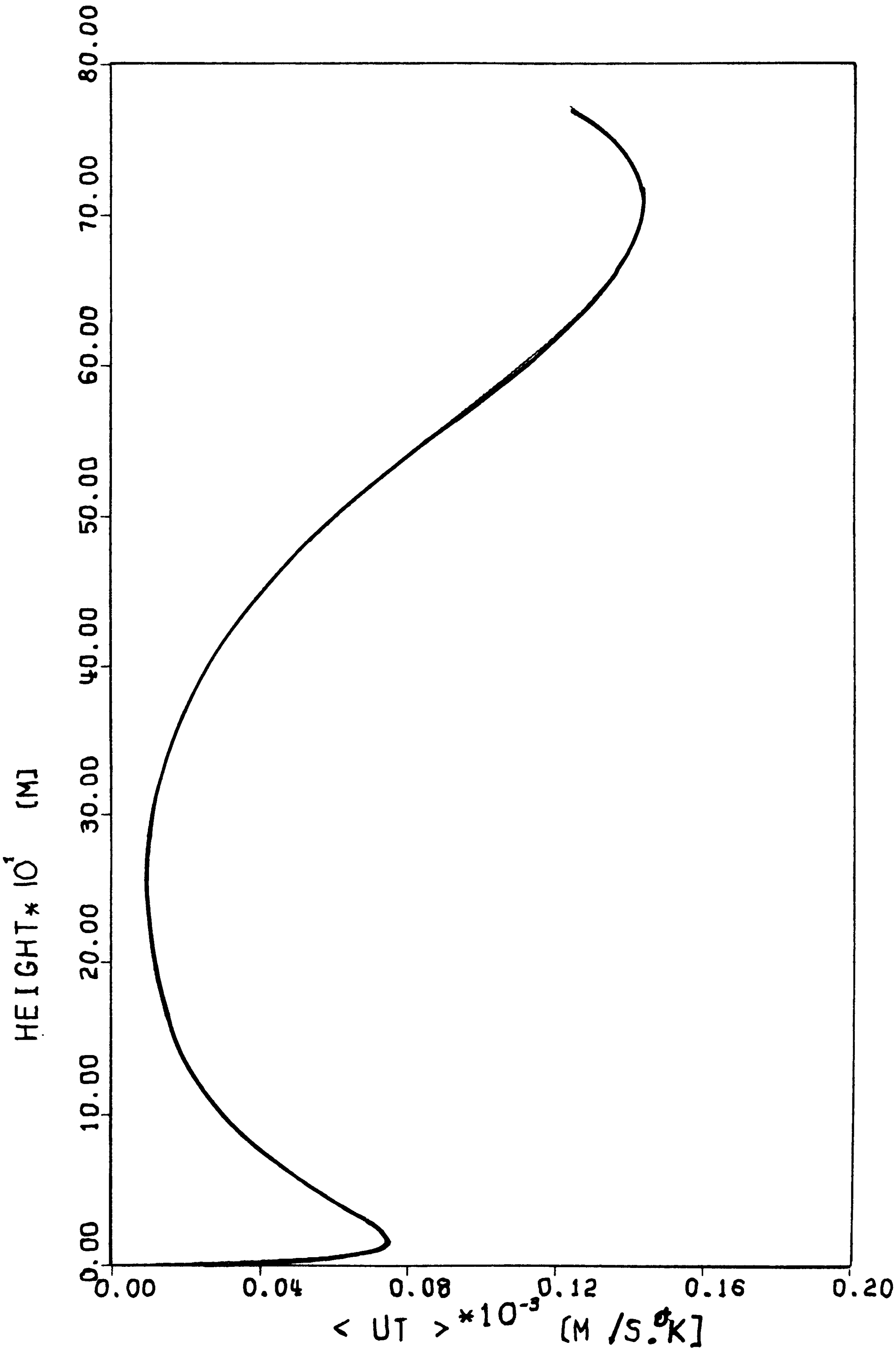


Figure 5.8

PARADISE (P2-3) CASE



Figu 5.9

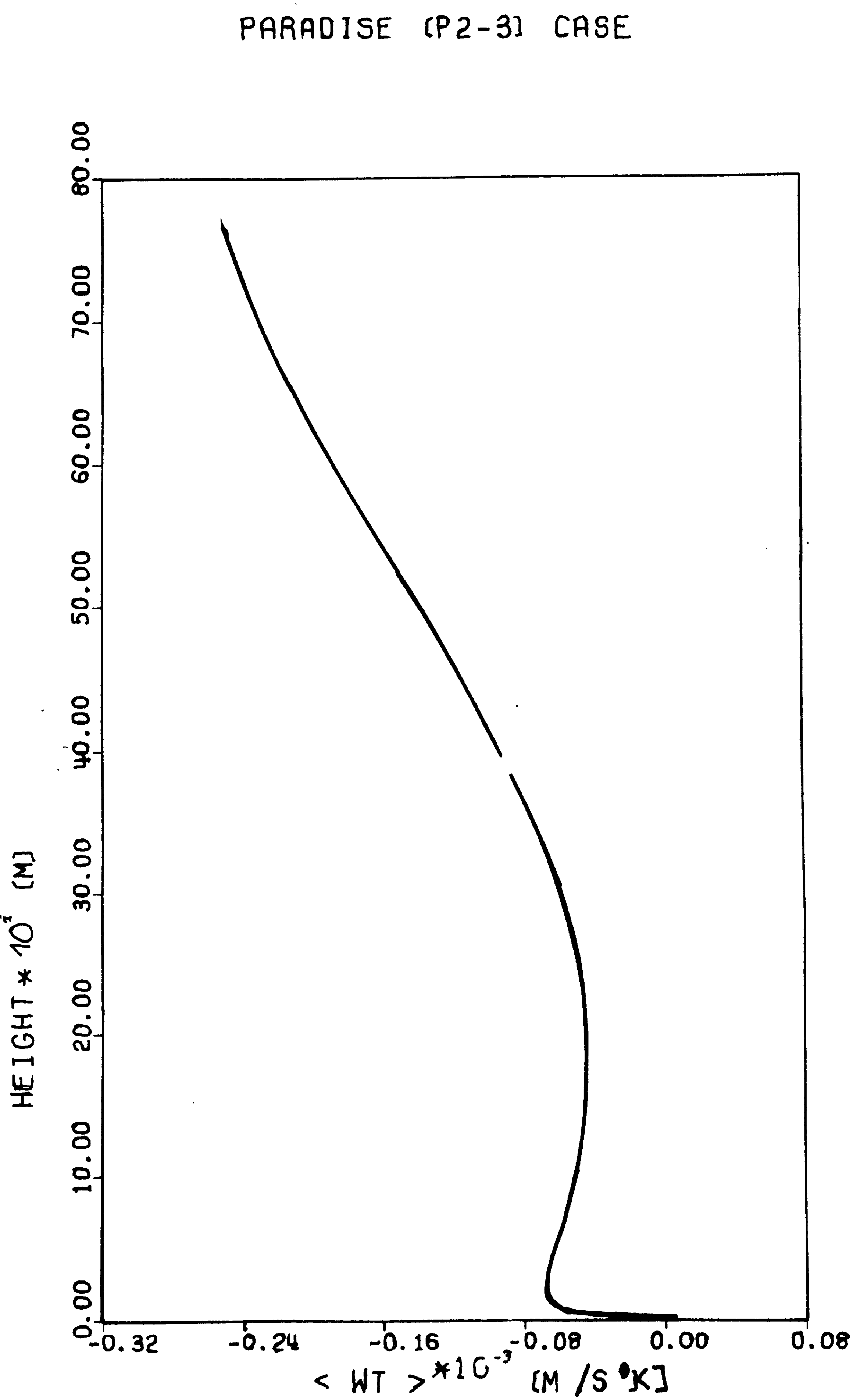

PARADISE (P2-3) CASE
HEIGHT * 10^1 (M)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
-0.32
-0.24
-0.16
-0.08
0.00
0.08
< WT > *10^-3 (M/S °K)

Figure 5.10

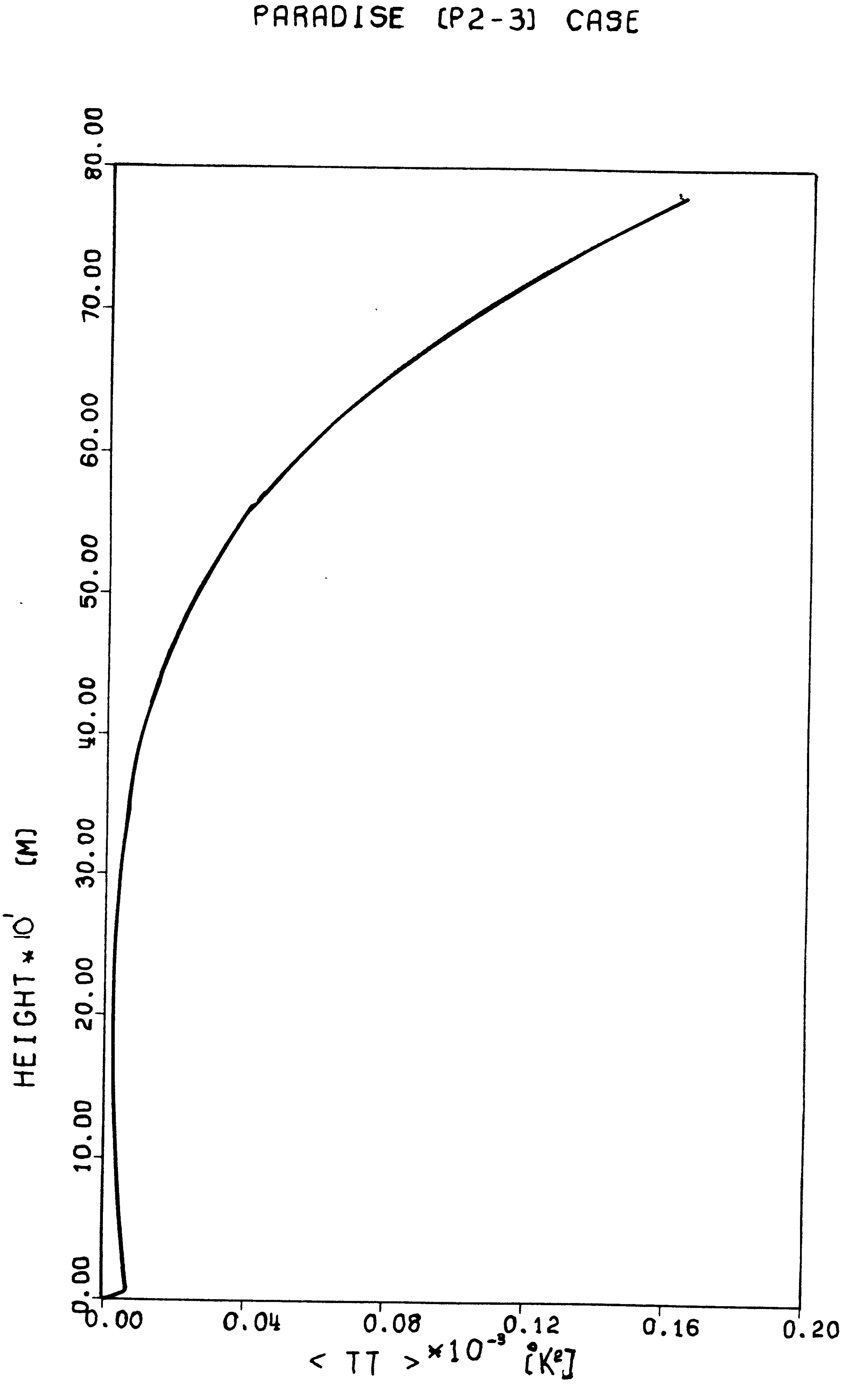

PARADISE [P2-3] CASE
HEIGHT * 10' [M]
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
0.04
0.08
0.12
0.16
0.20
< TT > *10^-3 [K²]

Figure 5.11

PARADISE (P2-3) CASE

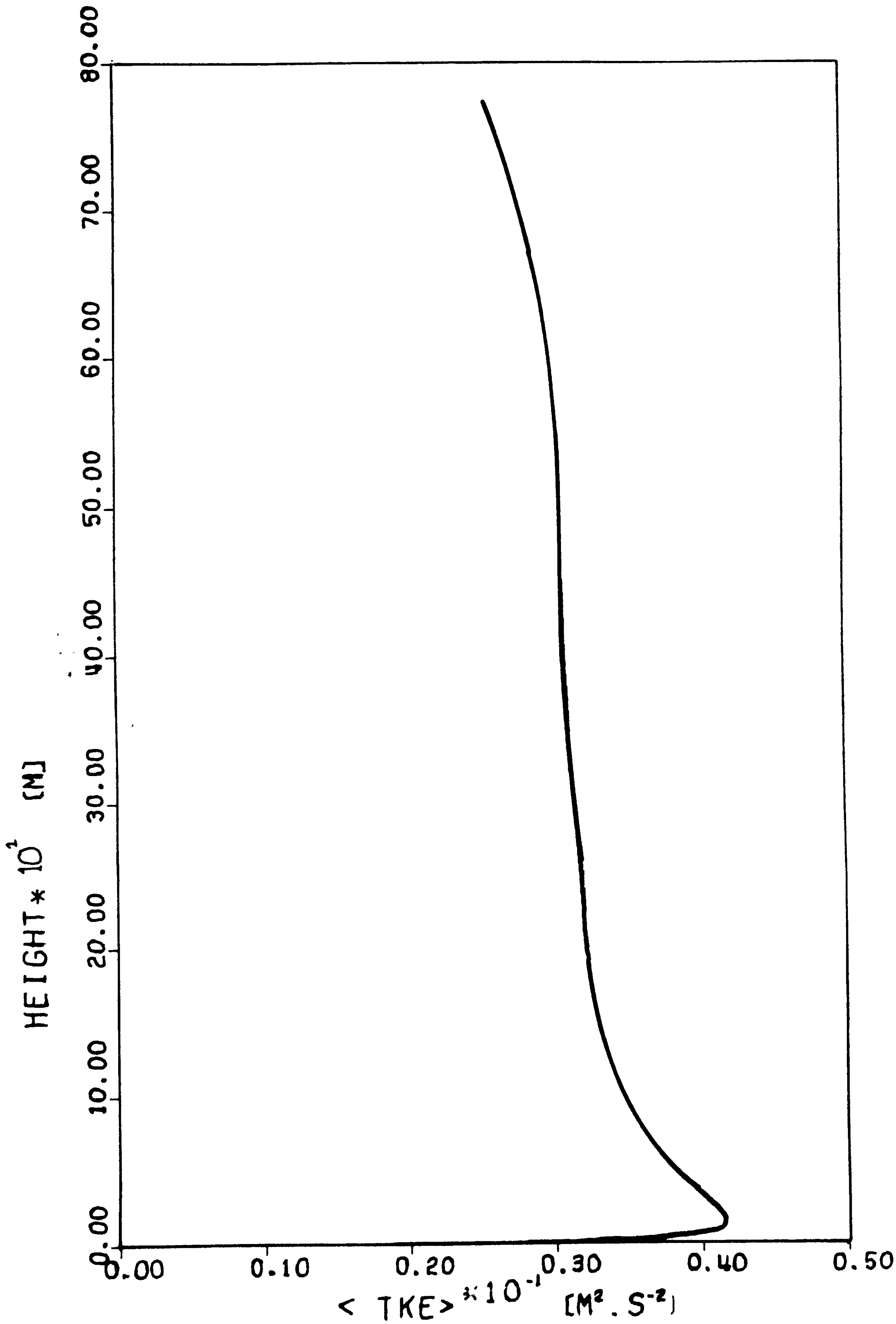


Figure 5.12

the saturation density of the parcel. Using the logic described in the cloud microphysics model in Chapter 2 the parcel is forced to saturation at a temperature compatible with the liquid and vapor content of the plume. It is found that the plume condenses a certain amount of vapor in order to reach that state, therefore increasing the amount of liquid water contained in the air parcel. A value of 1.84 10^{-4} lbm/ft^3 is obtained. The plume is initialized at a temperature of 53.85^{O}F while the ambient temperature is 36^{O}F. This temperature difference results in a strong upward acceleration due to the high buoyancy of the plume. The wind speed at the tower level is relatively low, inferring only a small deflection to the plume in the downwind direction. The high updraft velocity (6 m/sec) of the plume at the tower exit results in an increased vertical acceleration making the plume rise to about 700 m above the tower top. The simulation is started with two cells initialized (see Fig. 5.3) After 50 seconds of development (see Fig. 5. 4) a vortex circulation has formed in the vicinity of the warm cells, and mixing has brought the warmest fluid cell (2.5) from 53.853^{O}F to 42.87^{O}F. The strongest updraft (10.5 ft/sec) occurs in the warmest cell.

After 300 seconds of development (see Fig. 5.5) the plume has quickly risen to 300 m. Considerable mixing has brought the warmest cell temperature to ambient values. As earlier, the plume vortex circulation is very easy to identify and it occupies a progressively

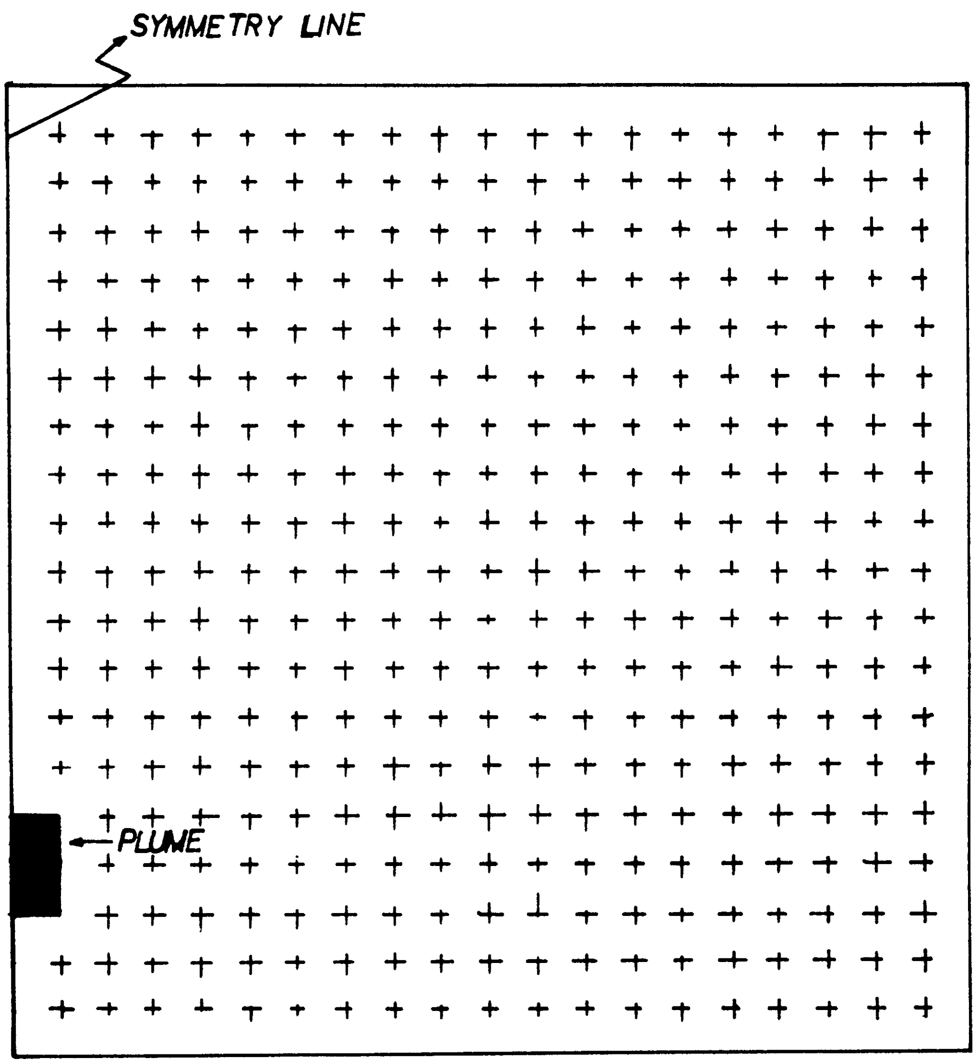


Figure 5.13

The Computer Mesh Showing the Initialized Plume Cell

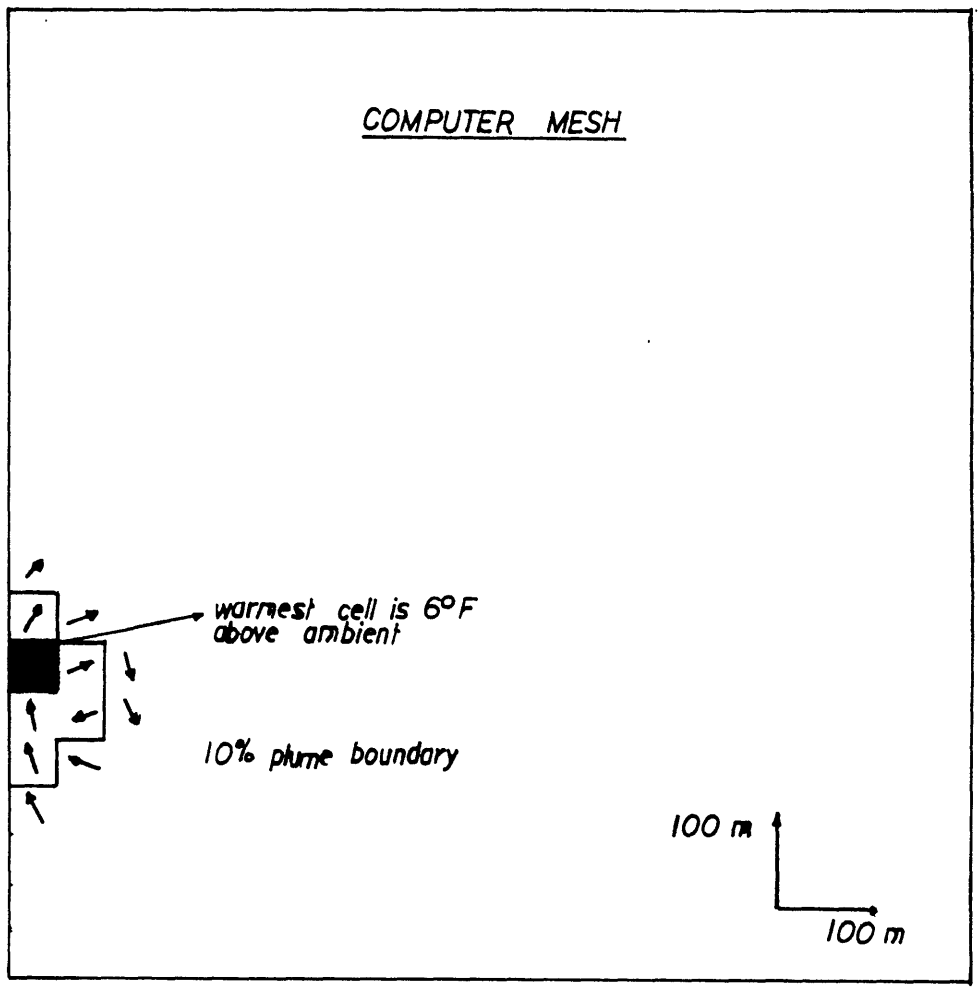


Figure 5.14

February 3rd, 1976 Visible Plume Cross-section at 50 sec of Simulation Showing the Internal Circulation

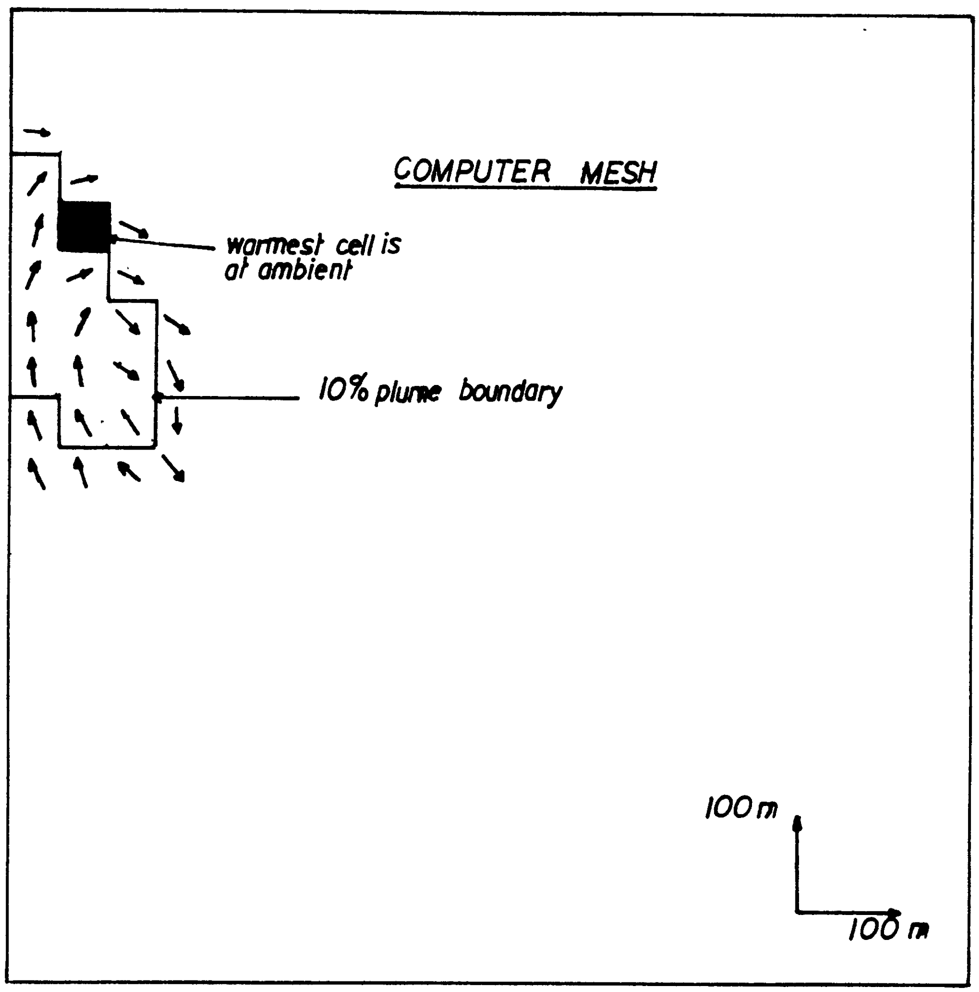


Figure 5.15

February 3rd, 1976 Visible Plume Cross-section at 350 sec of Simulation Showing the Internal Circulation larger area as the plume cross section grows. The turbulence kinetic energy is about twice that of the ambient field.

After 500 seconds the plume is at the ambient temperature and the amount of vapor contained in the plume has dropped below the saturation value, rendering the plume almost invisible, nevertheless the plume internal circulation is still noticeable. The criterion for visibility, is to consider as being visible any cell whose moisture content is within 10% of the saturation value. This criterion is due to the uncertainty in predicting exactly the amount of liquid water present in the plume which in our case is obtained by the Dibelius and Ederhoff correlation which gives an approximate value for the liquid water content of the plume, the quantity found to be important in the modeling of visible plume. Therefore, a good prediction of this quantity is necessary. If one compares the amount of water which can be available at the exit of the cooling tower with the amount predicted at the exit of the cooling tower, one finds a quite large difference.

The water available is computed using the temperature above the drift eliminator and the temperature at the tower exit. The former one is 92.3°F which yields a saturation density of $2.26\ 10^{-3}$ lbm/ft^3. The latter one is 81°F which respectively yields a saturation density of $1.579\ 10^{-3}$ lbm/ft^3 the difference between the two uration densities ($0.69\ 10^{-3}$ lbm/ft^3) represent the available water. This difference is quite large compared to the amount of liquid water.

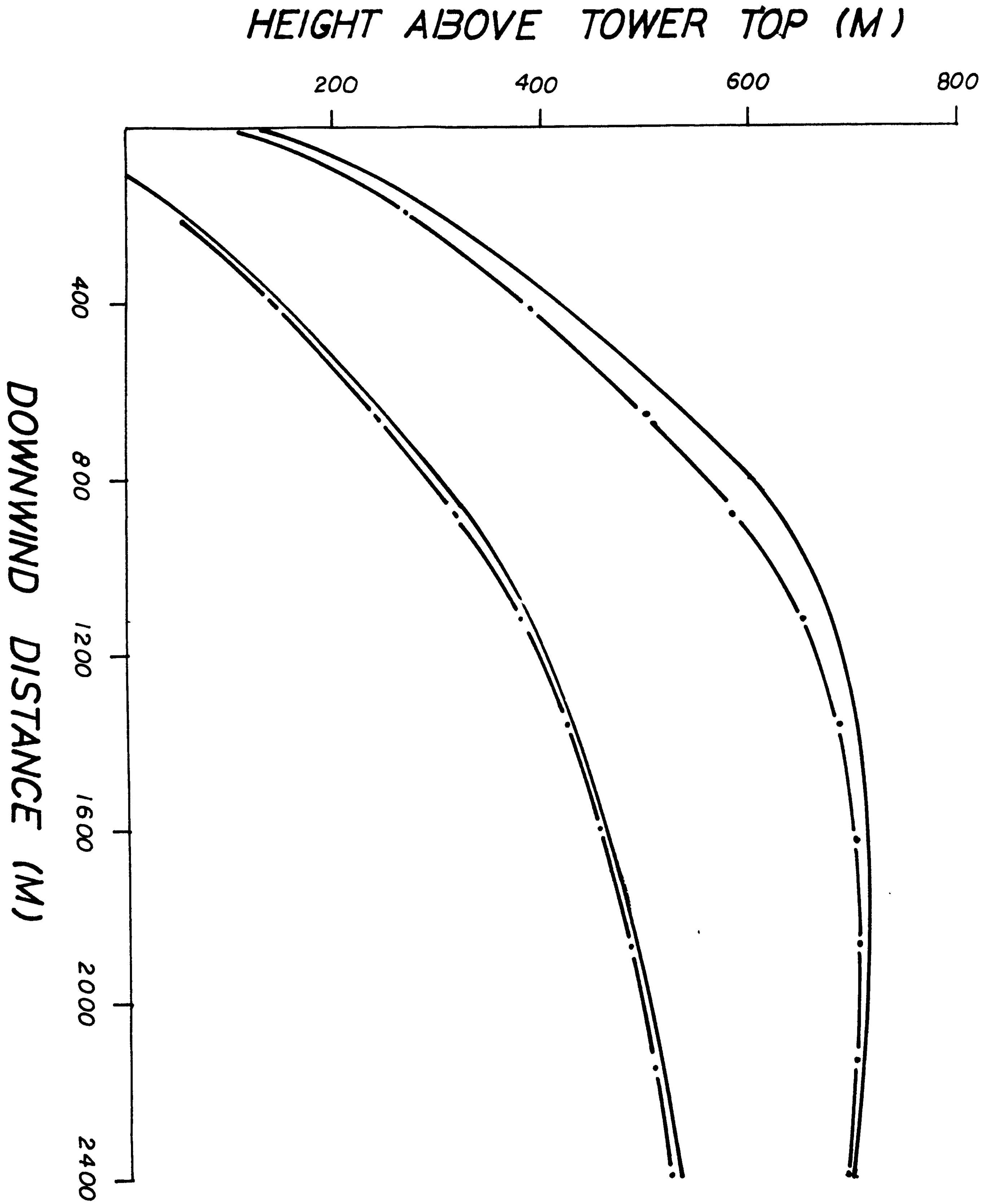


Figure 5.16

Comparison of Measured and Simulated Plumes

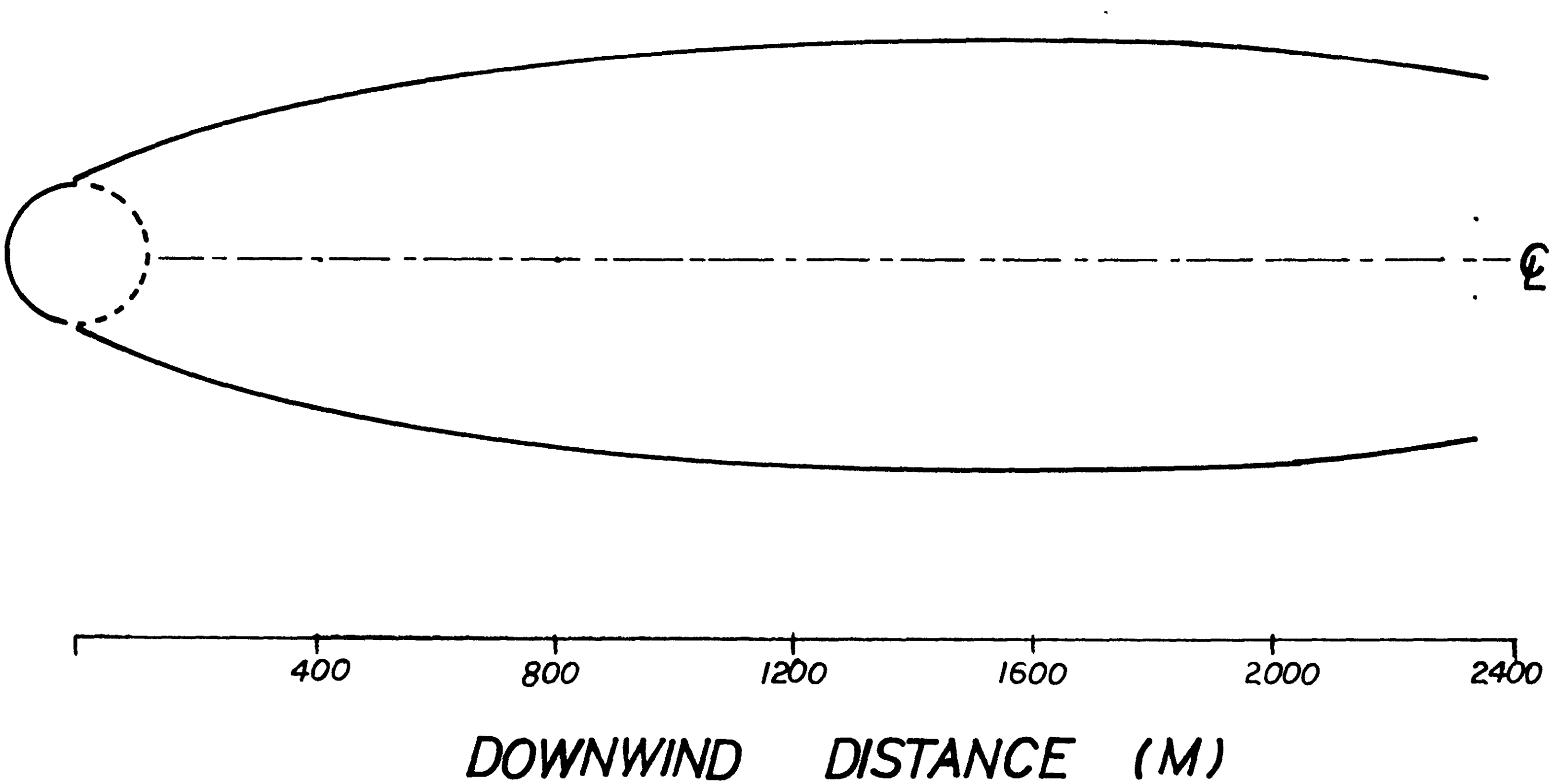


Figure 5.16b

Top View of the Plume (P2-3)

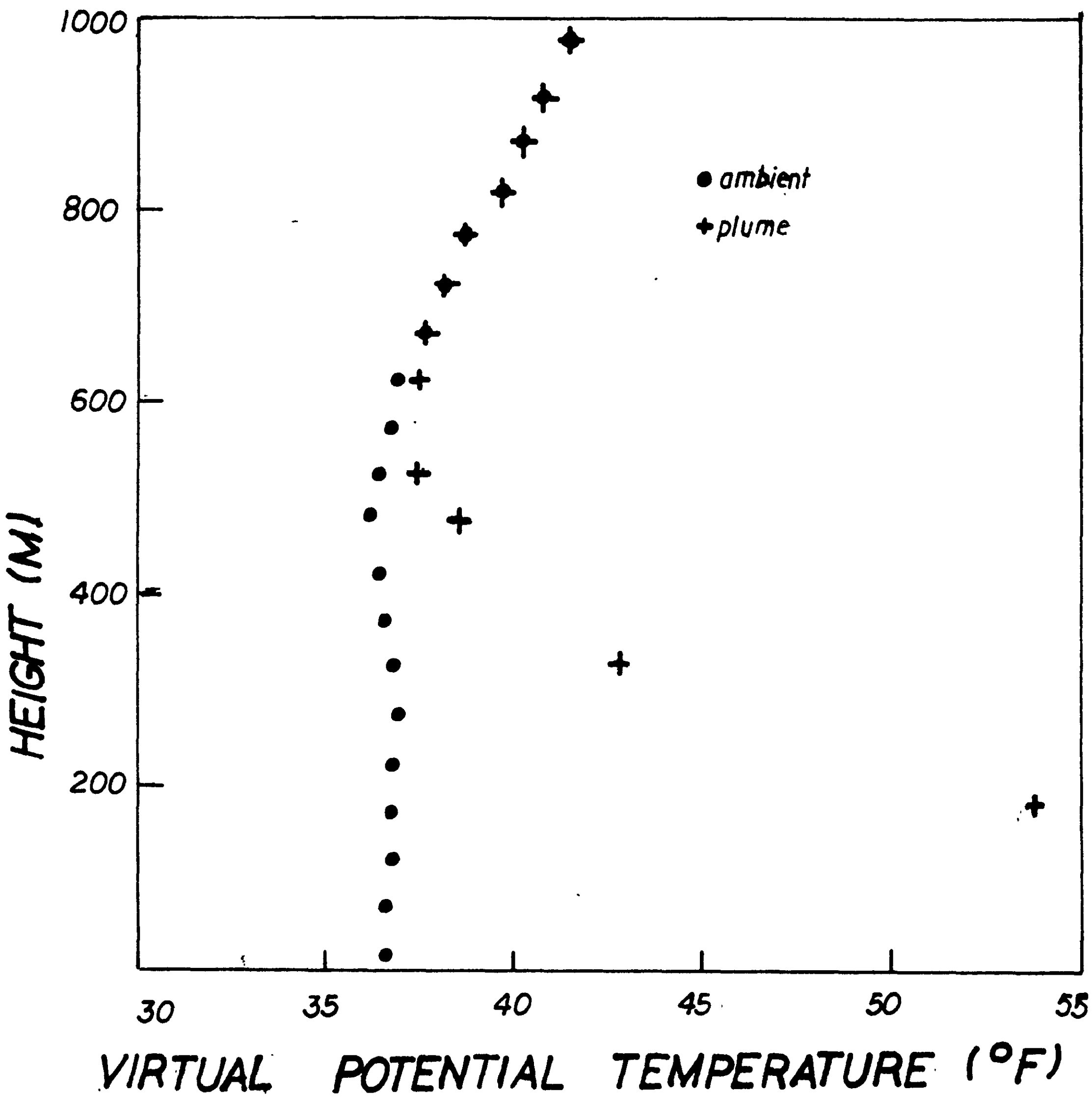


Figure 5.17

Time Evolution of the Plume Temperature

predicted by the Dibelius and Ederhoff correlation, which suggests that the correlation may underpredict the initial liquid water content of the plume. Given those large differences it is plausible to assume a cell to be visible when its vapor density is within 10% of saturation. The entire simulation was carried to a distance of 3.6 kilometers downwind. The plume becomes invisible after 3 kilometers (the vapor density drops below 10% of the saturation value). The simulation reproduces very well the observed plume (Fig. 5.16) although some of the operating parameters of the cooling tower are not systematically measured but rather are deduced from the data base.

5.2.4 The Paradise February 10th Visible Plume

In this case a cloud layer in an inversion of unmeasured vertical extent caps a deep neutral layer. Two moisture instabilities produce a long, high plume. Figure 5.18 shows the experimental result for this plume. The relatively low wind speed results in a weak vertical shear. This case resembles in many aspects the former one, however the very cold temperature makes it very difficult to measure properly the relative humidity (because of icing). This is a difficulty since the saturation density is very small at low temperatures. This difficulty is seen very clearly in the scatter of the data corresponding to the vapor density. The cold ambient temperature (27°F) results in a very strong buoyancy effect which raises the plume very quickly to a height of 550 m above the tower top after 50 seconds. The

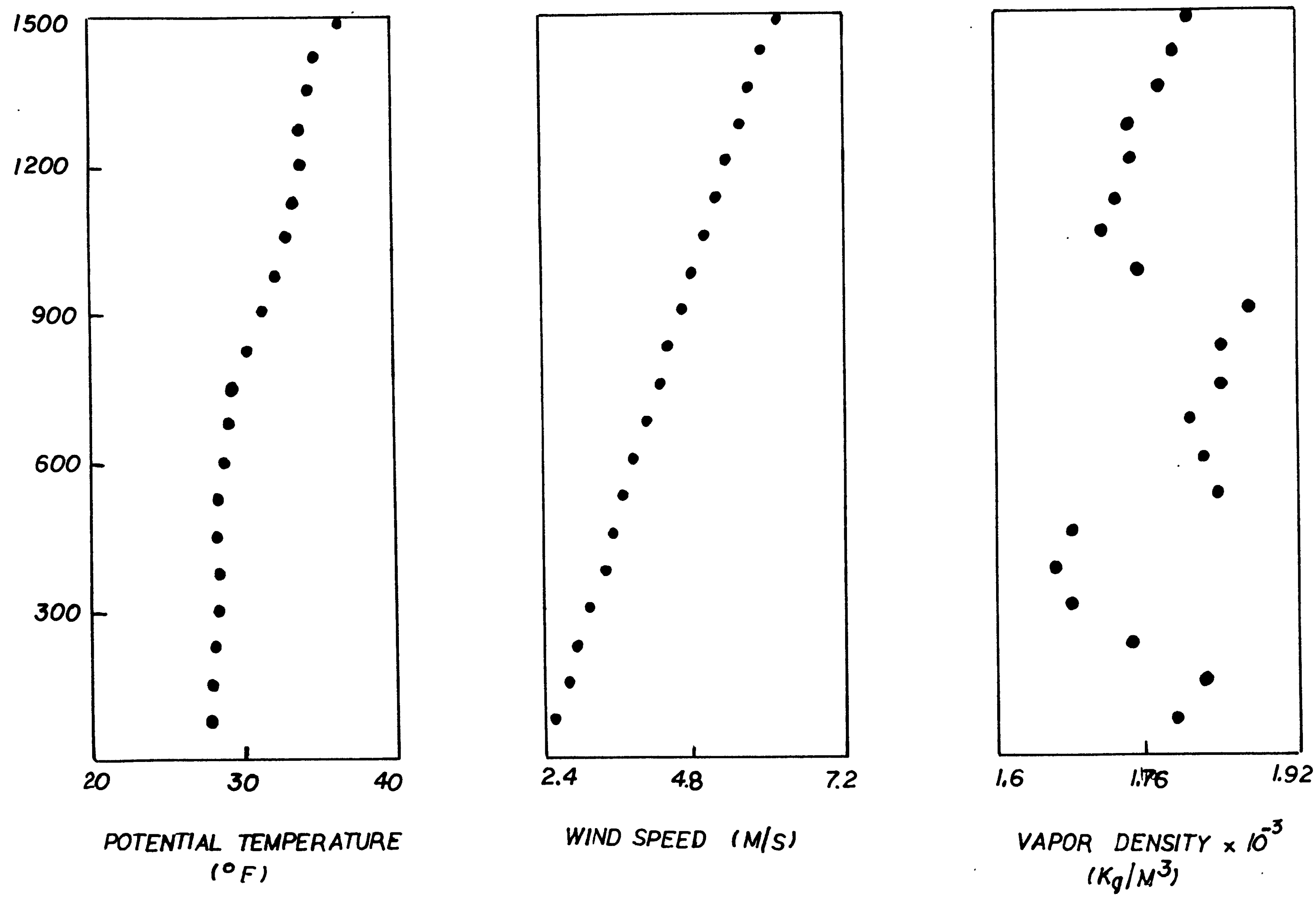


Figure 5.18

February 10th Paradise Plume. Measured Input Profiles average wind speed of 3 m/s is not strong enough to bend the plume over rapidly. The high water content at the tower exit is responsible for the very long and high plume which is observed. A saturation deficit of the atmosphere is 0.5 gr/kg. This amount of water is easily supplied by the plume through turbulent diffusion and convection and drive the surrounding atmosphere of the plume to saturation. This leads to a large spreading of the plume (see Fig. 5.18). Nevertheless the plume reaches the inversion layer located at a height of 1070 m after 400 sec. (Fig. 5.19). However, it does not penetrate the layer and begin evaporating. Although the ambient synoptic conditions are different from the former case, the basic hydrodynamic and turbulent features of both plumes are very similar. The difficulty in reproducing the measured plume exactly is attributed to inadequate measurements of the dew point temperature and therefore the vapor density. This case is a very difficult one and most models fail to simulate this plume adequately. Yet the turbulent plume model predicts accurately the length of the plume and the spreading. The plume rise is slightly over-predicted due to the lack of an adequate experimental data base. In order to test the sensitivity of the simulated plume behavior to the predictions of the atmospheric turbulence model the plume of February 3 was calculated using atmospheric turbulence profiles obtained for a neutral atmosphere rather than that of the slightly stable lower layer capped by a stable layer.

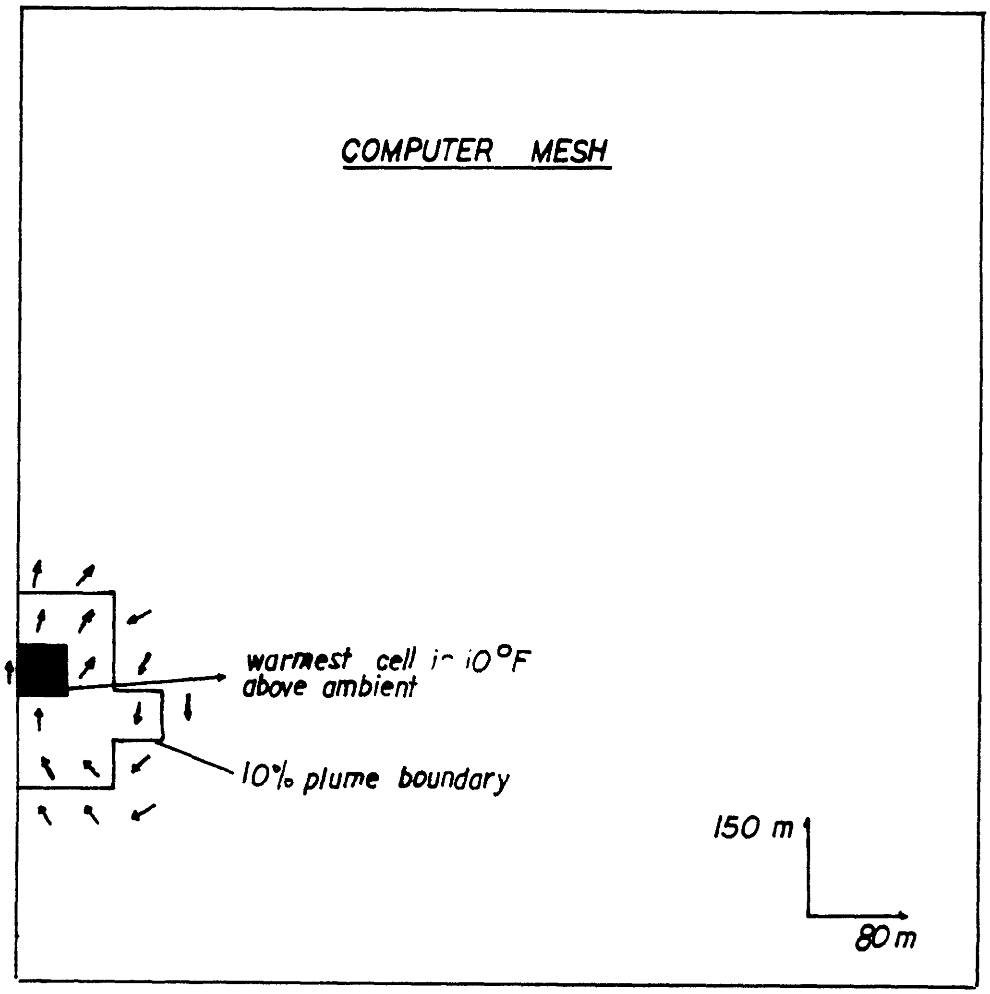


Figure 5.18a

February 10th Visible Plume Cross-section at 50 sec of Simulation Showing the Circulation

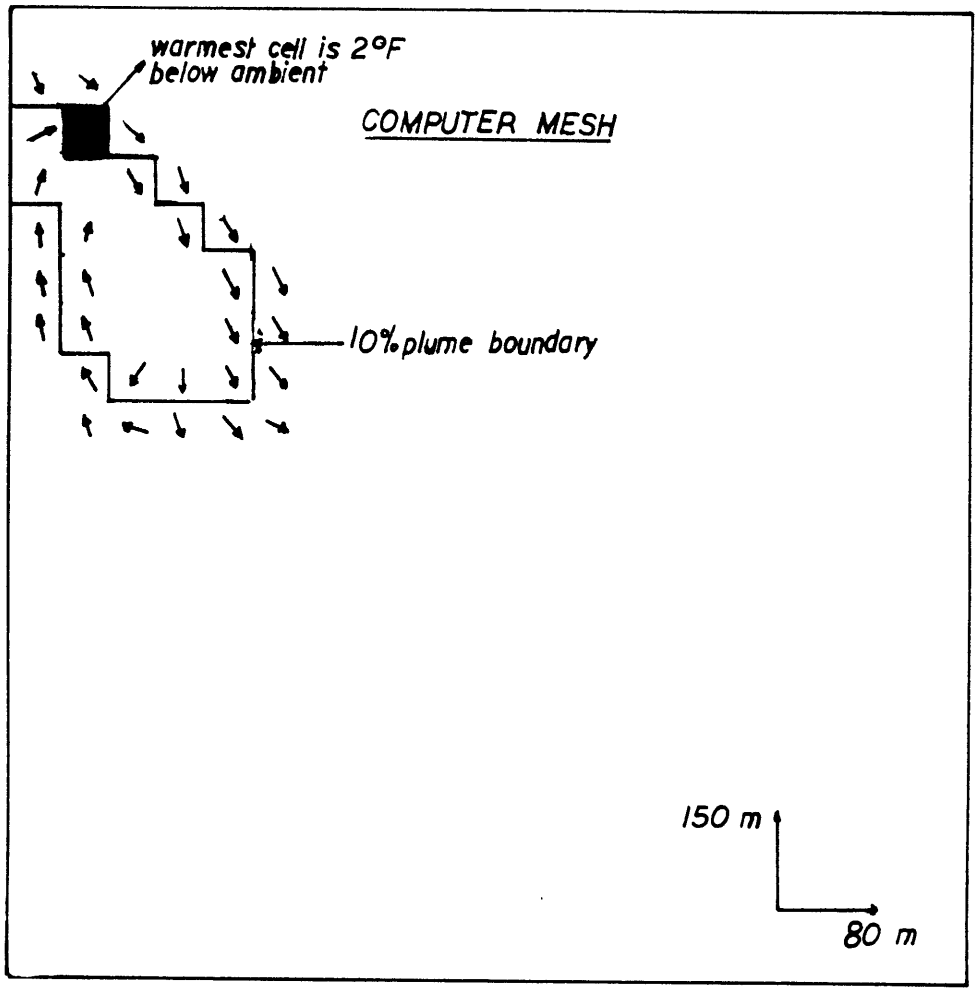


Figure 5.18b

February 10th, 1976 Visible Plume Cross-section at 350 sec of Simulation Showing the Circulation

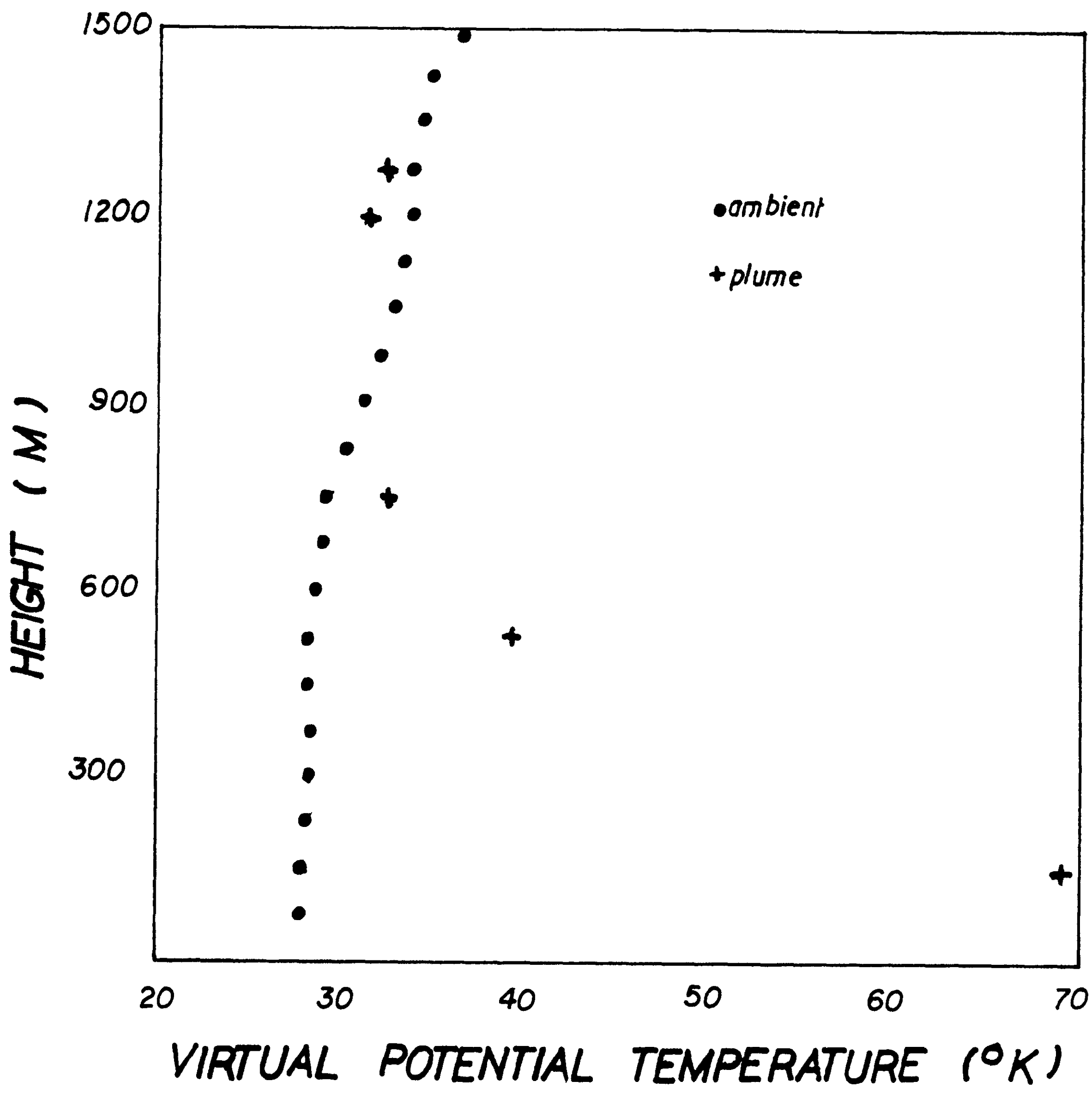


Figure 5.19

Febrary 10th Plume. Evolution of Plume Temperature as a Function of Height

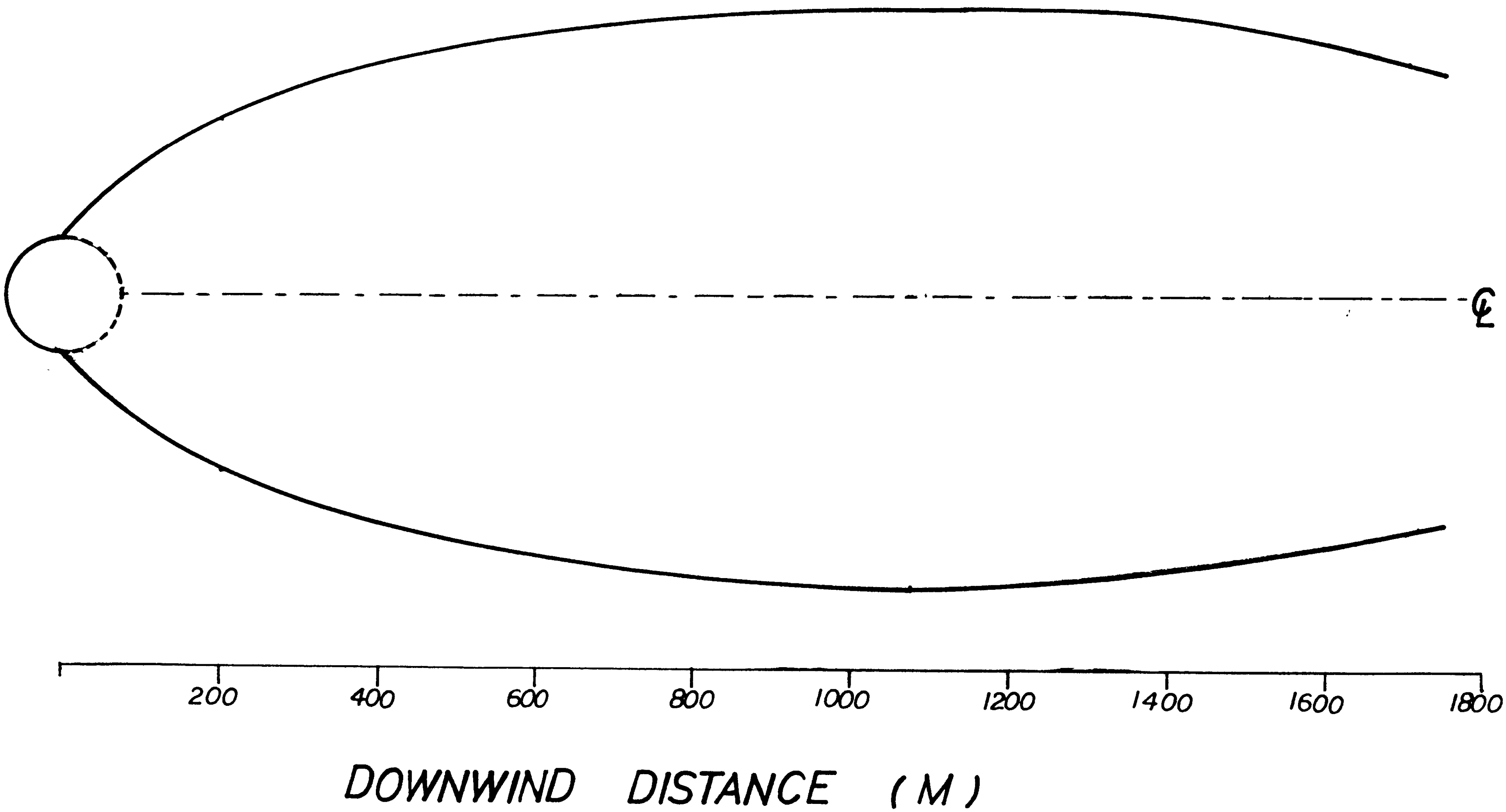


Figure 5.18

Top View of the Plume. Showing Extensive Spreading.

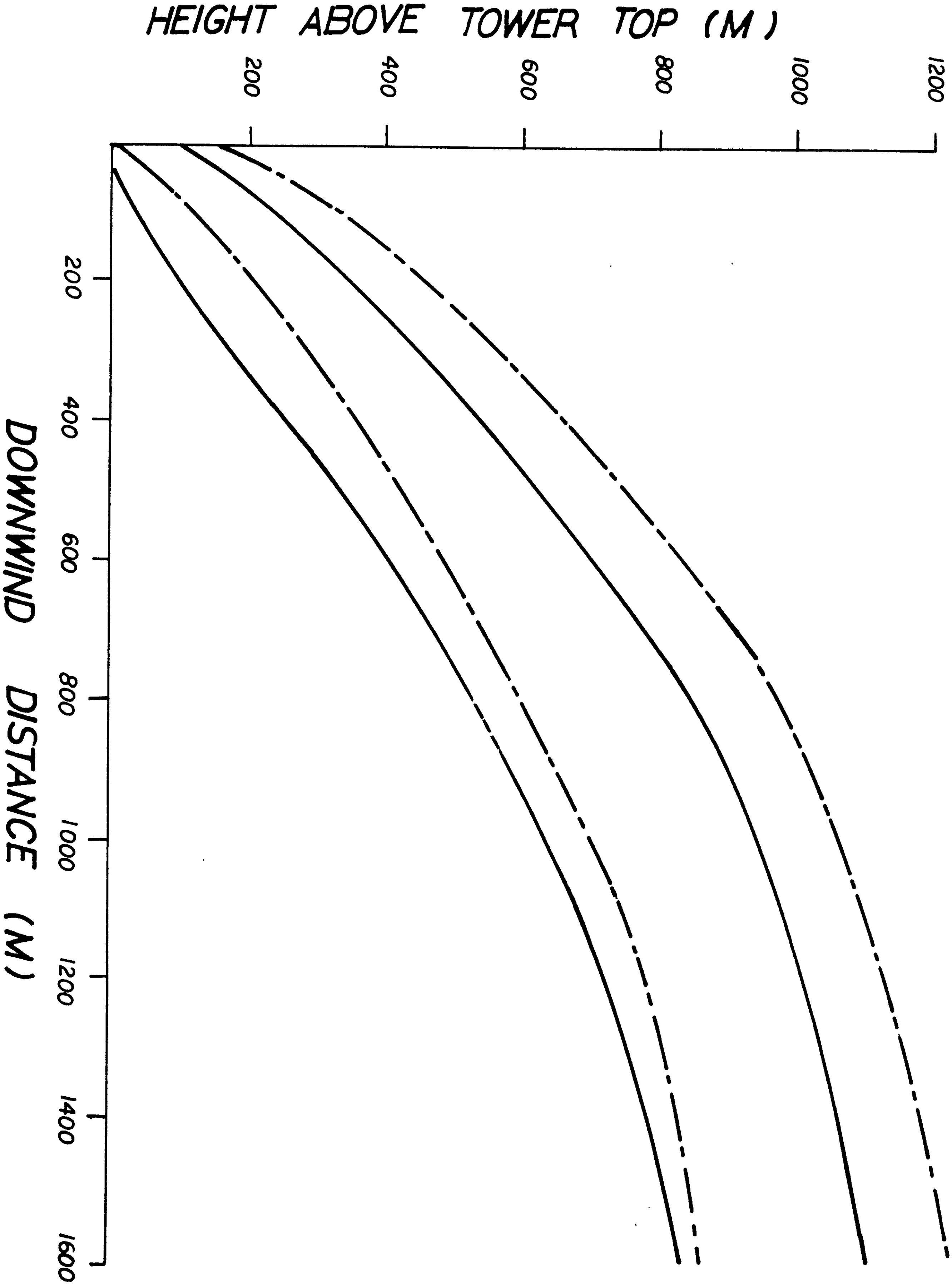


Figure 5.20

Comparison of Measured and Simulated Plumes

5.4 Sensitivity Analysis

The February 3rd plume has been initialized with the profiles for the turbulent kinetic energy and the turbulent kinematic viscosity obtained in the validation calculation for the neutral case of the P.B.L. As can be seen from Fig. 5.21 the maximum plume rise decreases by about 100 meters in comparison to the standard case. Given that the magnitude of the Reynolds stresses in the neutral case are greater than those computed for the February 3rd case, the higher degree of mixing calculated here results in a vanishing plume at a downwind distance of about 2.4 km while the former simulation results in a much longer plume (3.2 km). Therefore proper prediction of atmospheric turbulence is seen to be important if one wishes to model atmospheric dominated plumes adequately.

This also shows the importance of knowledge of the effects of atmospheric stability structure upon atmospheric turbulence. If one were to use only the lower atmosphere information available for the February 3rd case one might choose to characterize it as being neutrally stable, since it is in fact stable and not greatly different from neutral in that region. The consequence would then be serious errors in prediction of atmospheric turbulence and thus in plume behavior.

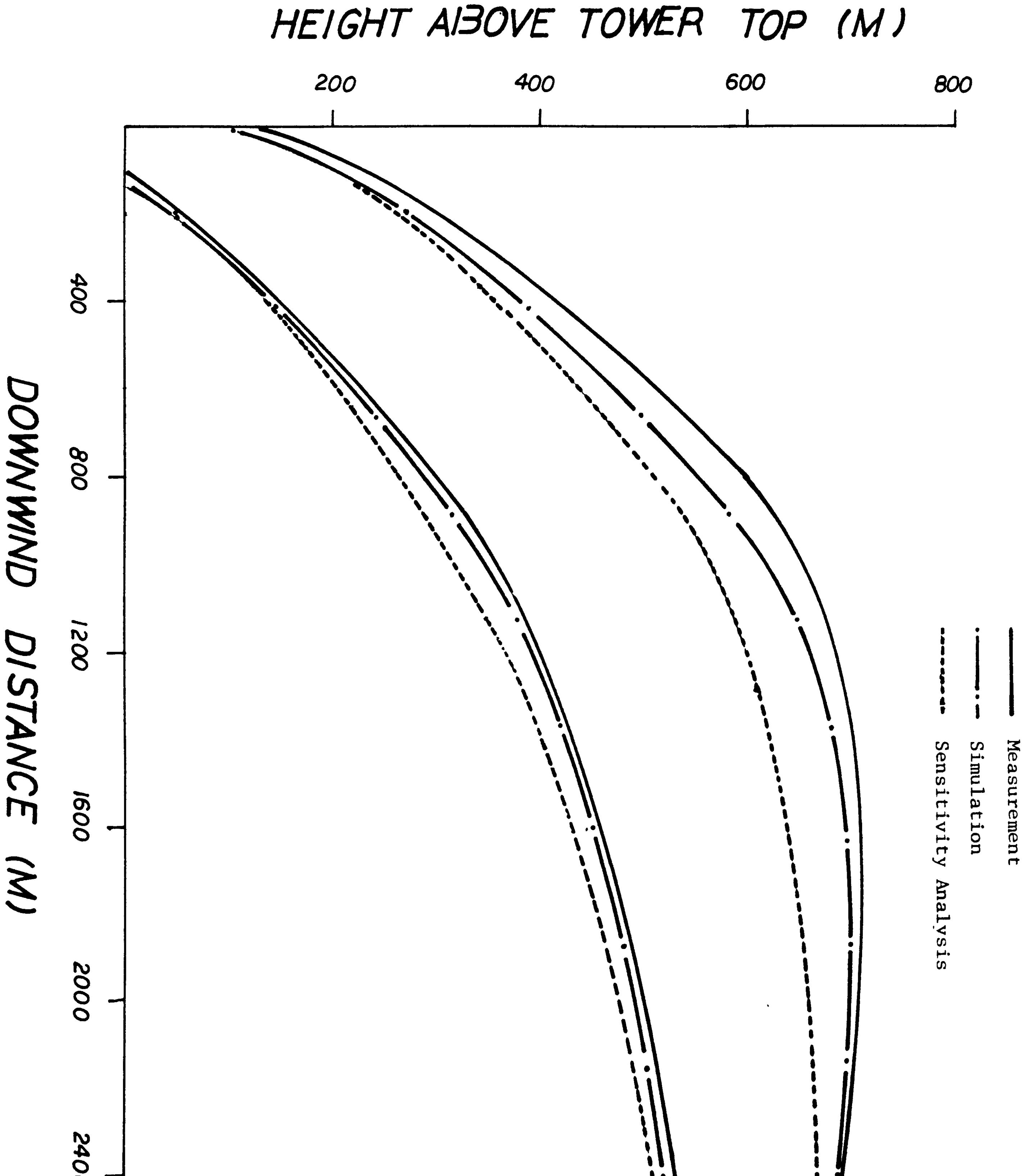


Figure 5.21

Comparison of Measured Plume with Computer Simulation, Showing Sensitivity Analysis

6 CONCLUSIONS

A widely applicable turbulent Buoyant Plume model has been developed along with a one-dimensional Planetary Boundary Layer model which computes the different atmospheric turbulent fluctuation correlations. The Planetary Boundary Layer model accounts properly for all the basic phenomena involved in atmospheric motion and yields the turbulent kinetic energy and the turbulent kinematic viscosity profiles required as input to the plume model. Among the three cases studied the model does best in the case of stable atmospheric stratification. The temperature correlations in the three cases are not in good agreement with the measurements. However, part of this difficulty is attributed to the poor accuracy of the experimental results. Nevertheless, the heat fluxes are irrelevant in the present version of the Plume model; only the Reynolds stresses are needed. Therefore, the inaccuracies of the temperature correlations do not affect the Final Plume Results. Given that medium scale turbulence dominates atmospheric motion the buoyancy corrected version of the k-σ and k-ε model results in different turbulence distributions from those without the correction. However, the effect of this change has not been tested for atmospheric motion. Cost limitations result, for some cases, in resolution difficulties. In the early time simulations of plume behavior the coupled Entrainment model used for plume initialization solve this problem by carrying the plume to a downwind distance where it has spread to an extent that resolution is no longer a critical difficulty.

The Results of Section 5 deal with visible plumes. Generally it found that very good agreement with field experiments is obtained. This indicates that the model in this present version is capable of simulation of plumes with which most of the "conventional" models have difficulty. As is also shown the model does well in very complex atmospheric condition, even with the lack of proper measurements characterizing the large scale synoptic conditions and cooling tower operating parameters. This is due to the fact that the model uses a more fundamental calculation than do simpler models, taking into account the complex transport phenomena involved in such flows. (Furthermore, the model provides an accurate starting point for the detailed description of other processes in a plume's chemical reactions, (acid rain), radiation dose rates, etc.

Nomenclature

A_0	initial line-vortex area (ft^2)
C	experimental constant, 1.9
C_p	heat capacity at constant pressure ($BTU/lb_m\ {}^\circ R$)
c_p^{moist}	heat capacity of moist air at constant pressure ($BTU/lb_m\ {}^\circ R$)
DT	timestep size (sec)
DY	cell width (ft)
DZ	cell height (ft)
$e_{sat}^{(T)}$	saturation vapor pressure of water (mb)
$E_\chi^{(i)}$	energy of the ith decay channel from pollutant species χ (MeV)
$F_\chi^{(i)}$	fractional energy deposition for ith radioactive decay channel from pollutant species χ
g	acceleration due to gravity (ft/sec^2)
g_i	vector acceleration due to gravity (ft/sec^2)
I	specific internal energy (BTU/lb_m)
k	thermal conductivity ($BTU/ft\text{-}sec\text{-}{}^\circ R$)
L	buoyancy parameter (ft)
L_{eddy}	eddy length scale (ft)
L_{vap}	latent heat of vaporization of water (BTU/lb_m)
N	experimental constant, 3.0
$\tilde{p}$	physically measurable pressure (millibars)
p	pressure perturbation about an adiabatic reference state (mb)
p_0	pressure in a quiet adiabatic atmosphere (mb)

$\tilde{u}_i, \tilde{u}_j$	velocity (ft/sec)
u_i, u_j	velocity (ft/sec)
$\bar{u}_i, \bar{u}_j$	time average velocity (ft/sec)
u'_i, u'_j	fluctuating velocity (ft/sec)
$\overline{u'_i u'_j}$	Reynolds stress tensor (ft^2/sec^2)
$\overline{u'_i \theta'}$	correlation of fluctuating velocity and temperature
$\overline{u'_i u'_j u'_k}$	triple correlation of fluctuating velocity (ft^3/sec^3)
v	crosswind velocity (ft/sec)
v_g	geostrophic wind (ft/sec)
w	vertical velocity (ft/sec)
$w_{mol,\chi}$	molecular weight of the pollutant species (lb_m/lb_m-mole)
x	downwind distance (ft)
x_i, x_j	cartesian coordinate (ft)
y	crosswind distance (ft)
z	height (ft)
z^*	height coordinate of virtual origin (ft)

<u>Greek Letters</u>

α, α_1	turbulence constants
γ_L	reciprocal turbulent Schmidt number for liquid water
γ_T	reciprocal turbulent Prandtl number for heat
γ_v	reciprocal turbulent Schmidt number for water vapor
γ_χ	reciprocal turbulent Schmidt number for pollutant
Γ	turbulence constant
Γ_1	turbulence constant

$\bar{p}$	time average pressure perturbation (mb)
p'	fluctuating pressure perturbation (mb)
Pr	Prandtl number
$q, q(y,z,t)$	turbulence kinetic energy per unit lb_m (ft^2/sec^2)
$q^{(z)}_{library}$	prescribed turbulence kinetic energy profile (ft^2/sec^2)
Q	heat (BTU)
Q_H	heat emitted at stack exit (BTU/sec)
R(T)	plume radius as a function of time (ft)
R_{dry}, R_d	gas constant for dry air (ft^3 mb/lb_m °R)
R_{vap}, R_v	gas constant for water vapor (ft^3 mb/lb_m °R)
Sc_{Liq}	Schmidt number for liquid water
Sc_{vap}	Schmidt number for water vapor
t,T	time (seconds)
t_0	x/u_0 (sec)
T*	time coordinate of virtual origin (sec)
$\tilde{T}$	physically measurable temperature (°R)
T	temperature perturbation about an adiabatic reference state (°R)
T_0	temperature in a quiet adiabatic atmosphere (°R)
T_s	temperature of stack effluent (°R)
$\tilde{T}_v$	virtual temperature (°R)
T_{v0}	virtual temperature in a quiet adiabatic atmosphere (°R)
u	downwind velocity (ft/sec)
u_0,U	windspeed, constant with height (ft/sec)
u_{eddy}	turbulent velocity scale in an eddy (ft/sec)

Γ_d	dry adiabatic lapse rate (°R/ft)
ε_h	eddy diffusivity of heat (ft^2/sec)
ε_m	eddy diffusivity of momentum (ft^2/sec)
ε_χ	eddy diffusivity of pollutant (ft^2/sec)
$\tilde{\theta}$	potential temperature (°R)
θ	potential temperature perturbation about an adiabatic reference state (°R)
θ_0	potential temperature in a quiet adiabatic atmosphere (°R)
$\bar{\theta}$	time average potential temperature (°R)
θ'	fluctuating potential temperature (°R)
θ_v	virtual potential temperature (°R)
θ_{v0}	virtual potential temperature in a quiet adiabatic atmosphere (°R)
$\bar{\theta}_v$	time average virtual potential temperature (°R)
θ'_v	fluctuating virtual potential temperature (°R)
$\lambda_x^{(i)}$	decay constant for ith radioactive decay channel from pollutant species χ (sec^{-1})
μ	dynamic viscosity (lb_m/sec. ft)
ν	kinematic viscosity (ft^2/sec)
ρ_{dry}	density of dry air (lb_m/ft^3)
ρ_{Liq}	liquid water density (lb_m/ft^3)
$\bar{\rho}_{Liq}$	time average liquid water density (lb_m/ft^3)
ρ'_{Liq}	fluctuating liquid water density (lb_m/ft^3)
ρ_s	density of stack effluent (lb_m/ft^3)
ρ_{sat}	saturation water vapor density (lb_m/ft^3)
ρ_{vap}	water vapor density (lbm/ft^3)
$\bar{\rho}_{vap}$	time average water vapor density (lb_m/ft^3)

ρ'_{vap}	fluctuating water vapor density (lbm/ft^3)
$\sigma, \sigma(y,z,t)$	eddy viscosity (same as ε_m)(ft^2/sec)
$\sigma^{(z)}_{library}$	prescribed eddy viscosity profile (ft^2/sec)
χ	pollutant density (lbm/ft^3)
Λ_1	turbulence model length scale
ξ	characteristic atmospheric length scale

LIST OF FIGURES

LIST OF TABLES

TABLES

References

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- APPENDIX A -

Appendix A

The Plume Turbulence Model

Transport equations for the Reynolds stresses can be derived directly from the Navier Stokes equations: the plume model adopts the approach developed by Stuhmiller, who writes a two equation set for turbulence. The velocity scale, which is obtained from the transport of the turbulent kinetic energy K, and the turbulent kinematic viscosity, σ, yielding the K-σ model. The plume model has been also implemented with a version of the K-ε model developed, following the work of Launder et. al. [ ]. Explicitly the mathematical formulation of the two models is as follows:

<u>K-σ Model</u>

$$\frac{\partial K}{\partial t} + u_j \frac{\partial K}{\partial x_j} = \frac{\sigma}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)^2 + \frac{\partial}{\partial x_j}\left[\Gamma\sigma \frac{\partial K}{\partial x_j}\right] - 4\alpha \frac{K^2}{\sigma}$$

$$+ \beta g_i \gamma_T \sigma \frac{\partial T}{\partial x_i} \qquad \text{(A.1)}$$

$$\frac{\partial \sigma}{\partial t} + u_j \frac{\partial \sigma}{\partial x_j} = \frac{\sigma^2}{4K}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)^2 + \frac{\sigma}{K}\frac{\partial}{\partial x_j}\left(\Gamma\,\sigma \frac{\partial K}{\partial x_j}\right)$$

$$+ \frac{\sigma}{K}\beta g_i \gamma_T \sigma \frac{\partial T}{\partial x_i} - \frac{\sigma^3}{K^2}\frac{\partial}{\partial x_j}\left(\Gamma K \frac{\partial}{\partial x_j}\left(\frac{K}{\sigma}\right)\right) - 4\alpha K \qquad \text{(A.2)}$$

<u>Modified K-ε Model</u>

$$\frac{\partial K}{\partial t} + u_j \frac{\partial K}{\partial x_j} = \frac{\sigma}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j} + \frac{\partial}{\partial x_j}\left(\frac{\sigma}{\sigma_K}\frac{\partial K}{\partial x_j}\right) - C_\mu \frac{K^2}{\sigma} + \beta g_i \gamma_T \frac{\partial T}{\partial x_i} \qquad \text{(A.3)}$$

$$\frac{\partial \sigma}{\partial t} + u_j \frac{\partial \sigma}{\partial x_j} = \frac{\sigma^2}{K}\left(\Lambda - \frac{C_\Lambda}{2}\right)\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)^2 + \frac{2\sigma}{K}\frac{\partial}{\partial x_j}\left(\frac{\sigma}{\sigma_K}\frac{\partial K}{\partial x_j}\right)$$

$$- \frac{\sigma^2}{K^2}\frac{\partial}{\partial x_j}\left(\frac{2K}{\sigma_\varepsilon}\right)\frac{\partial}{\partial x_j}\left(\frac{K}{\sigma}\right) - \frac{1}{\sigma_\varepsilon}\left(\frac{\sigma}{K}\right)^4 \frac{\partial}{\partial x_j}\left(\frac{K^4}{\sigma^3}\frac{\partial \sigma}{\partial x_j}\right) - C_\mu(2 - C_2)K \quad \text{(A.4)}$$

where σ_k, σ_ε, C_Λ, C_2, and C_μ are the model free parameters.

In all the calculations carried in this work the original K-σ model has been used. Nevertheless the modified K-ε model has been tested. It was found that the K-ε model estimates of the Reynolds stresses are generally higher in magnitude than the K-σ estimates. by approximately 30 percent.

Stuhmiller [61] used a plausible explanation of the turbulence transport phenomena to derive the K-σ model. His argument can be summarized as follows. In a fully developed turbulent flow, fluctuations exist on every scale from the largest allowed by the geometry of the boundaries to the smallest allowed by molecular viscosity. However, it is often possible to distinguish two spatial regimes: one that is primarily responsible for the diffusivity of the flow, and a second for the viscous dissipation of energy. Based on these assumptions, the turbulence spectrum may be simplified to one in which there are only two eddy sizes: the production scale, which interacts strongly with the mean flow by transferring energy from the mean motion to the large eddies, and the dissipation scale, which represents the small scale motion leading ultimately to the creation of heat.

In two dimensions the turbulence model can be written as follows:

$$\frac{Dg}{Dt} = 2\sigma\left[\left(\frac{\partial v}{\partial y}\right)^2 + \frac{\Lambda}{2}\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2\right] - 4\ \alpha g \sigma^{-1}$$

$$+ \Gamma \left(\frac{\partial}{\partial y}\sigma\frac{\partial g}{\partial y} + \frac{\partial}{\partial z}\sigma\frac{\partial g}{\partial z}\right) + \beta g_i\ \gamma_T \sigma \frac{\partial T}{\partial z} \tag{A.5}$$

$$\frac{D\sigma}{Dt} = \frac{\sigma^2}{g}\left[\left(\frac{\partial v}{\partial y}\right)^2 + \frac{\Lambda}{2}\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2\right] - \alpha g + \frac{\sigma}{g}\beta\ g\ \gamma_T\ \sigma\frac{\partial T}{\partial z}$$

$$+ \Gamma\frac{\sigma}{g}\left[\left(\frac{\partial}{\partial y}\sigma\frac{\partial g}{\partial y}\right) + \left(\frac{\partial}{\partial z}\sigma\frac{\partial g}{\partial z}\right)\right] - \Gamma_1\left[\frac{\sigma^3}{g^2}\frac{\partial}{\partial y}g\frac{\partial}{\partial y}\left(\frac{g}{\sigma}\right) + \frac{\partial}{\partial z}g\frac{\partial}{\partial z}\left(\frac{g}{\sigma}\right)\right] \tag{A.6}$$

where all the model constants are defined in Table A.1. This turbulence model interacts directly with the behavior of the plume. Henceforth, the magnitudes of the turbulent kinetic energy and the kinematic viscosity depend strongly on the velocity and temperature field. In contrast with the turbulence parameters of the planetary boundary layer which are steady state values independent of the internal circulation of the plume. The flow diagram in Fig. A.1 shows the solution scheme of the plume model and how the turbulence parameter interacts with the mean field.

For a more detailed structure and operation information, the users manual [3] and Chen's doctoral thesis [Ref. 4] provide a description of VARR-II, a complete list of the partial differential equations involved, and a concise explanation of the solution algorithm.

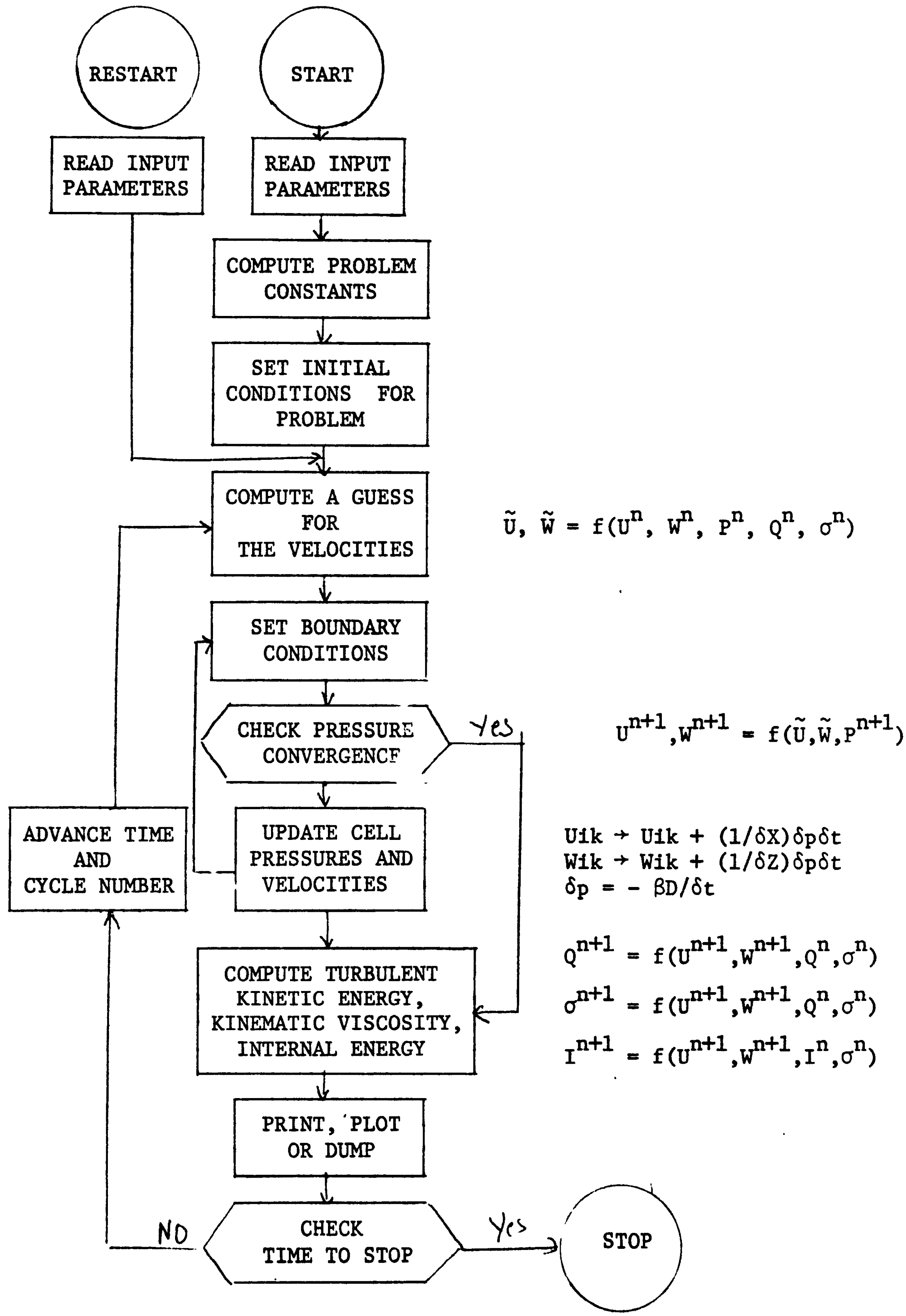

Fig. A.1: Flow Diagram of Solution Scheme

Table 4.1

Generalized Turbulence Model Constants

eneralized onstant	K–σ Model: Original Symbol	K–σ Model: Value	K–ε Model: Original Symbol	K–ε Model: Value
k_1	---	0.25	$(1 - C_1/2) = 1 - 1.44/2$	0.28
k_2	--	1.0	--	2.0
k_3	Γ	1.5	$1/\sigma_k = 1/1.0$	1.0
k_4	Γ_1	0.75	$2/\sigma_\varepsilon = 2/1.3$	1.54
k_5	--	0	--	1.0
k_6	$\alpha_1 = \alpha_0$	0.01125	$\dfrac{C_\mu(2 - C_2)}{4} = \dfrac{(0.09)(2 - 1.92)}{4}$	0.0018
k_7	α	0.045	$C_\mu/4$	0.0225
	from VARR-II		from TEACH-T	

- APPENDIX B -

Appendix B

The Clausius Clapeyron Equation

The expression giving the slope of a curve separating two phases in the p-T diagram is known as the Clapeyron equation. To derive it we shall make use of the fact that the chemical potential μ has the same value for two phases of a pure substance in equilibrium.

$$\mu_f = \mu_g \tag{B.1}$$

Since the chemical potential is identical to the specific Gibbs function in the case of a single component simple compressible substance.

$$G_f = G_g \tag{B.2}$$

It follows that: $dG_f = dG_g$

or:

$$-S_f dT_f + v_f dp_f = -S_g dT_g + v_g dp_g \tag{B.3}$$

since $dg = -SdT + vdp$

But: $dT_f = dT_g = dT$

and $dP_f = dp_g = dp$

Since the changes in temperature and pressure are the same for both phases

$$\frac{dp}{dT} = \frac{S_g - S_f}{v_g - v_f} = \frac{S_{fg}}{v_{fg}} \tag{B.4}$$

However:

$$TdS = dh - vdp$$

Given that the temperature and pressure are constant in a phase change

$$TS_{fg} = h_{fg}$$

substituting in (B.4)

we have:

$$\frac{dp}{dT} = \frac{h_{fg}}{Tv_{fg}} \qquad \text{(B.5)}$$

for liquid-vapor phase changes at relatively low pressure, v_g is much larger than v_f. We may therefore approximate in (B.5) v_{fg} by v_g in addition, the vapor may be assumed to behave like an ideal gas at low pressure; Introducing these approximations into B.5 we have:

$$\frac{dp}{dT} = \frac{h_{fg}}{Tv_g} = \frac{h_{fg}}{TRT/p}$$

$$h_{fg} = \frac{RT^2}{p}\frac{dp}{dT} \qquad \text{(B.6)}$$

if we neglect the T and p dependence of h_{fg} (B.6) can be integrated to give:

$$\text{en}\,\frac{P_2}{P_1} = \frac{h_{fg}}{R}\;\frac{1}{T_2} - \frac{1}{T_1} \qquad \text{(B.7)}$$

Equation B.7 indicates that when h_{fg} may be assumed to be constant and when the vapor may be assumed to behave like an ideal gas, the vapor pressure is a function of temperature only.

- APPENDIX C -

SAMPLE OUTPUT FROM THE PLUME MODEL

PARADISE (P2-3) CASE

```
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X                X                X                X                X                X                X
X     ( 1,22)    X     ( 2,22)    X     ( 3,22)    X     ( 4,22)    X     ( 5,22)    X     ( 6,22)    X     ( 7,22)
X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F
X  RHS= 0.0      X  RHS= 0.0      X  RHS= 0.0      X  RHS= 0.0      X  RHS= 0.0      X  RHS= 0.0      X  RHS= 0.0
       2      0.0      10     0.0      10     0.0      10     0.0      10     0.0      10     0.0      10     0.0
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0 0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0
X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X                X                X                X                X                X                X
X     ( 1,21)    X     ( 2,21)    X     ( 3,21)    X     ( 4,21)    X     ( 5,21)    X     ( 6,21)    X     ( 7,21)
X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F   X   42.104   F
X  RHS= 2.742E-04 X  RHS= 2.742E-04 X  RHS= 2.742E-04 X  RHS= 2.742E-04 X  RHS= 2.742E-04 X  RHS= 2.742E-04 X  RHS= 2.742E-04
      10      0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04 X  VAP= 1.070E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X                X                X                X                X                X                X
X     ( 1,20)    X     ( 2,20)    X     ( 3,20)    X     ( 4,20)    X     ( 5,20)    X     ( 6,20)    X     ( 7,20)
X   41.446   F   X   41.446   F   X   41.446   F   X   41.446   F   X   41.446   F   X   41.446   F   X   41.446   F
X  RHS= 2.750E-04 X  RHS= 2.750E-04 X  RHS= 2.750E-04 X  RHS= 2.750E-04 X  RHS= 2.750E-04 X  RHS= 2.750E-04 X  RHS= 2.750E-04
      10      0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0
X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02
X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.140E-04 X  VAP= 1.140E-04 X  VAP= 1.140E-04 X  VAP= 1.140E-04 X  VAP= 1.140E-04 X  VAP= 1.140E-04 X  VAP= 1.140E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X                X                X                X                X                X                X
X     ( 1,19)    X     ( 2,19)    X     ( 3,19)    X     ( 4,19)    X     ( 5,19)    X     ( 6,19)    X     ( 7,19)
X   40.788   F   X   40.788   F   X   40.788   F   X   40.788   F   X   40.788   F   X   40.788   F   X   40.788   F
X  RHS= 2.756E-04 X  RHS= 2.756E-04 X  RHS= 2.756E-04 X  RHS= 2.756E-04 X  RHS= 2.756E-04 X  RHS= 2.756E-04 X  RHS= 2.756E-04
      10      0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0
X  TNU= 4.700E-02 X  TNU= 4.700E-02 X  TNU= 4.700E-02 X  TNU= 4.700E-02 X  TNU= 4.700E-02 X  TNU= 4.700E-02 X  TNU= 4.700E-02
X  TKE= 2.300E-02 X  TKE= 2.300E-02 X  TKE= 2.300E-02 X  TKE= 2.300E-02 X  TKE= 2.300E-02 X  TKE= 2.300E-02 X  TKE= 2.300E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.220E-04 X  VAP= 1.220E-04 X  VAP= 1.220E-04 X  VAP= 1.220E-04 X  VAP= 1.220E-04 X  VAP= 1.220E-04 X  VAP= 1.220E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X                X                X                X                X                X                X
X     ( 1,18)    X     ( 2,18)    X     ( 3,18)    X     ( 4,18)    X     ( 5,18)    X     ( 6,18)    X     ( 7,18)
X   40.129   F   X   40.129   F   X   40.129   F   X   40.129   F   X   40.129   F   X   40.129   F   X   40.129   F
X  RHS= 2.763E-04 X  RHS= 2.763E-04 X  RHS= 2.763E-04 X  RHS= 2.763E-04 X  RHS= 2.763E-04 X  RHS= 2.763E-04 X  RHS= 2.763E-04
      10      0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0       1     0.0
X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02
X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.300E-04 X  VAP= 1.300E-04 X  VAP= 1.300E-04 X  VAP= 1.300E-04 X  VAP= 1.300E-04 X  VAP= 1.300E-04 X  VAP= 1.300E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  0.0        , CYCLE NUMBER =     0 ,  PRESSURE ITERATION NUMBER =   0 , DT =  1.0000E-02
```

```
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1,17)     X    ( 2,17)     X    ( 3,17)     X    ( 4,17)     X    ( 5,17)     X    ( 6,17)     X    ( 7,17)
X   39.478  F    X   39.478  F    X   39.478  F    X   39.478  F    X   39.478  F    X   39.478  F    X   39.478  F
X RHS= 2.770E-04 X RHS= 2.770E-04 X RHS= 2.770E-04 X RHS= 2.770E-04 X RHS= 2.770E-04 X RHS= 2.770E-04 X RHS= 2.770E-04
     10      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0
X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01
X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.380E-04 X VAP= 1.380E-04 X VAP= 1.380E-04 X VAP= 1.380E-04 X VAP= 1.380E-04 X VAP= 1.380E-04 X VAP= 1.380E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1,16)     X    ( 2,16)     X    ( 3,16)     X    ( 4,16)     X    ( 5,16)     X    ( 6,16)     X    ( 7,16)
X   38.798  F    X   38.798  F    X   38.798  F    X   38.798  F    X   38.798  F    X   38.798  F    X   38.798  F
X RHS= 2.775E-04 X RHS= 2.775E-04 X RHS= 2.775E-04 X RHS= 2.775E-04 X RHS= 2.775E-04 X RHS= 2.775E-04 X RHS= 2.775E-04
     10      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0
X TNU= 2.560E-01 X TNU= 2.560E-01 X TNU= 2.560E-01 X TNU= 2.560E-01 X TNU= 2.560E-01 X TNU= 2.560E-01 X TNU= 2.560E-01
X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.450E-04 X VAP= 1.450E-04 X VAP= 1.450E-04 X VAP= 1.450E-04 X VAP= 1.450E-04 X VAP= 1.450E-04 X VAP= 1.450E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1,15)     X    ( 2,15)     X    ( 3,15)     X    ( 4,15)     X    ( 5,15)     X    ( 6,15)     X    ( 7,15)
X   38.417  F    X   38.417  F    X   38.417  F    X   38.417  F    X   38.417  F    X   38.417  F    X   38.417  F
X RHS= 2.807E-04 X RHS= 2.807E-04 X RHS= 2.807E-04 X RHS= 2.807E-04 X RHS= 2.807E-04 X RHS= 2.807E-04 X RHS= 2.807E-04
     10      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0
X TNU= 3.270E-01 X TNU= 3.270E-01 X TNU= 3.270E-01 X TNU= 3.270E-01 X TNU= 3.270E-01 X TNU= 3.270E-01 X TNU= 3.270E-01
X TKE= 2.770E-02 X TKE= 2.770E-02 X TKE= 2.770E-02 X TKE= 2.770E-02 X TKE= 2.770E-02 X TKE= 2.770E-02 X TKE= 2.770E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.570E-04 X VAP= 1.570E-04 X VAP= 1.570E-04 X VAP= 1.570E-04 X VAP= 1.570E-04 X VAP= 1.570E-04 X VAP= 1.570E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1,14)     X    ( 2,14)     X    ( 3,14)     X    ( 4,14)     X    ( 5,14)     X    ( 6,14)     X    ( 7,14)
X   37.530  F    X   37.530  F    X   37.530  F    X   37.530  F    X   37.530  F    X   37.530  F    X   37.530  F
X RHS= 2.789E-04 X RHS= 2.789E-04 X RHS= 2.789E-04 X RHS= 2.789E-04 X RHS= 2.789E-04 X RHS= 2.789E-04 X RHS= 2.789E-04
     10      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0
X TNU= 3.880E-01 X TNU= 3.880E-01 X TNU= 3.880E-01 X TNU= 3.880E-01 X TNU= 3.880E-01 X TNU= 3.880E-01 X TNU= 3.880E-01
X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.650E-04 X VAP= 1.650E-04 X VAP= 1.650E-04 X VAP= 1.650E-04 X VAP= 1.650E-04 X VAP= 1.650E-04 X VAP= 1.650E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1,13)     X    ( 2,13)     X    ( 3,13)     X    ( 4,13)     X    ( 5,13)     X    ( 6,13)     X    ( 7,13)
X   37.343  F    X   37.343  F    X   37.343  F    X   37.343  F    X   37.343  F    X   37.343  F    X   37.343  F
X RHS= 2.845E-04 X RHS= 2.845E-04 X RHS= 2.845E-04 X RHS= 2.845E-04 X RHS= 2.845E-04 X RHS= 2.845E-04 X RHS= 2.845E-04
     10      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0        1      0.0
X TNU= 4.350E-01 X TNU= 4.350E-01 X TNU= 4.350E-01 X TNU= 4.350E-01 X TNU= 4.350E-01 X TNU= 4.350E-01 X TNU= 4.350E-01
X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.740E-04 X VAP= 1.740E-04 X VAP= 1.740E-04 X VAP= 1.740E-04 X VAP= 1.740E-04 X VAP= 1.740E-04 X VAP= 1.740E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  0.0          , CYCLE NUMBER =     0 ,  PRESSURE ITERATION NUMBER =    0 , DT =  1.0000E-02
```

```
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X               X               X               X               X               X               X
X    ( 1,12)    X    ( 2,12)    X    ( 3,12)    X    ( 4,12)    X    ( 5,12)    X    ( 6,12)    X    ( 7,12)
X   36.934  F   X   36.934  F   X   36.934  F   X   36.934  F   X   36.934  F   X   36.934  F   X   36.934  F
X RHS= 2.878E-04 X RHS= 2.878E-04 X RHS= 2.878E-04 X RHS= 2.878E-04 X RHS= 2.878E-04 X RHS= 2.878E-04 X RHS= 2.878E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01
X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.800E-04 X VAP= 1.800E-04 X VAP= 1.800E-04 X VAP= 1.800E-04 X VAP= 1.800E-04 X VAP= 1.800E-04 X VAP= 1.800E-04
X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X               X               X               X               X               X               X
X    ( 1,11)    X    ( 2,11)    X    ( 3,11)    X    ( 4,11)    X    ( 5,11)    X    ( 6,11)    X    ( 7,11)
X   36.754  F   X   36.754  F   X   36.754  F   X   36.754  F   X   36.754  F   X   36.754  F   X   36.754  F
X RHS= 2.935E-04 X RHS= 2.935E-04 X RHS= 2.935E-04 X RHS= 2.935E-04 X RHS= 2.935E-04 X RHS= 2.935E-04 X RHS= 2.935E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01
X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.890E-04 X VAP= 1.890E-04 X VAP= 1.890E-04 X VAP= 1.890E-04 X VAP= 1.890E-04 X VAP= 1.890E-04 X VAP= 1.890E-04
X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X               X               X               X               X               X               X
X    ( 1,10)    X    ( 2,10)    X    ( 3,10)    X    ( 4,10)    X    ( 5,10)    X    ( 6,10)    X    ( 7,10)
X   36.567  F   X   36.567  F   X   36.567  F   X   36.567  F   X   36.567  F   X   36.567  F   X   36.567  F
X RHS= 2.995E-04 X RHS= 2.995E-04 X RHS= 2.995E-04 X RHS= 2.995E-04 X RHS= 2.995E-04 X RHS= 2.995E-04 X RHS= 2.995E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01
X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 1.930E-04 X VAP= 1.930E-04 X VAP= 1.930E-04 X VAP= 1.930E-04 X VAP= 1.930E-04 X VAP= 1.930E-04 X VAP= 1.930E-04
X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X               X               X               X               X               X               X
X    ( 1, 9)    X    ( 2, 9)    X    ( 3, 9)    X    ( 4, 9)    X    ( 5, 9)    X    ( 6, 9)    X    ( 7, 9)
X   36.629  F   X   36.629  F   X   36.629  F   X   36.629  F   X   36.629  F   X   36.629  F   X   36.629  F
X RHS= 3.081E-04 X RHS= 3.081E-04 X RHS= 3.081E-04 X RHS= 3.081E-04 X RHS= 3.081E-04 X RHS= 3.081E-04 X RHS= 3.081E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01
X TKE= 3.090E-02 X TKE= 3.090E-02 X TKE= 3.090E-02 X TKE= 3.090E-02 X TKE= 3.090E-02 X TKE= 3.090E-02 X TKE= 3.090E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 2.050E-04 X VAP= 2.050E-04 X VAP= 2.050E-04 X VAP= 2.050E-04 X VAP= 2.050E-04 X VAP= 2.050E-04 X VAP= 2.050E-04
X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X               X               X               X               X               X               X
X    ( 1, 8)    X    ( 2, 8)    X    ( 3, 8)    X    ( 4, 8)    X    ( 5, 8)    X    ( 6, 8)    X    ( 7, 8)
X   36.671  F   X   36.671  F   X   36.671  F   X   36.671  F   X   36.671  F   X   36.671  F   X   36.671  F
X RHS= 3.166E-04 X RHS= 3.166E-04 X RHS= 3.166E-04 X RHS= 3.166E-04 X RHS= 3.166E-04 X RHS= 3.166E-04 X RHS= 3.166E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X TNU= 5.400E-01 X TNU= 5.400E-01 X TNU= 5.400E-01 X TNU= 5.400E-01 X TNU= 5.400E-01 X TNU= 5.400E-01 X TNU= 5.400E-01
X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02
X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03 X CHI= 1.000E-03
X VAP= 2.210E-04 X VAP= 2.210E-04 X VAP= 2.210E-04 X VAP= 2.210E-04 X VAP= 2.210E-04 X VAP= 2.210E-04 X VAP= 2.210E-04
X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0      X LIQ= 0.0
TIME=  0.0          , CYCLE NUMBER =     0 ,  PRESSURE ITERATION NUMBER =    0 , DT =  1.0000E-02
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XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1, 7)     X    ( 2, 7)     X    ( 3, 7)     X    ( 4, 7)     X    ( 5, 7)     X    ( 6, 7)     X    ( 7, 7)
X   36.726  F    X   36.726  F    X   36.726  F    X   36.726  F    X   36.726  F    X   36.726  F    X   36.726  F
X  RHS= 3.256E-04 X  RHS= 3.256E-04 X  RHS= 3.256E-04 X  RHS= 3.256E-04 X  RHS= 3.256E-04 X  RHS= 3.256E-04 X  RHS= 3.256E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01
X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 2.300E-04 X  VAP= 2.300E-04 X  VAP= 2.300E-04 X  VAP= 2.300E-04 X  VAP= 2.300E-04 X  VAP= 2.300E-04 X  VAP= 2.300E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    6.600  XXXXXXXXX    6.600  XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X         V      X         V      X                X                X                X                X
X    ( 1, 6)     X    ( 2, 6)     X    ( 3, 6)     X    ( 4, 6)     X    ( 5, 6)     X    ( 6, 6)     X    ( 7, 6)
X   53.852  F    X   53.852  F    X   36.539  F    X   36.539  F    X   36.539  F    X   36.539  F    X   36.539  F
X  RHS= 5.910E-04 X  RHS= 5.910E-04 X  RHS= 3.319E-04 X  RHS= 3.319E-04 X  RHS= 3.319E-04 X  RHS= 3.319E-04 X  RHS= 3.319E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01
X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02
X  CHI= 1.000E-01 X  CHI= 1.000E-01 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 5.880E-04 X  VAP= 5.880E-04 X  VAP= 2.380E-04 X  VAP= 2.380E-04 X  VAP= 2.380E-04 X  VAP= 2.380E-04 X  VAP= 2.380E-04
X  LIQ= 1.840E-04 X  LIQ= 1.840E-04 X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    6.600  XXXXXXXXX    6.600  XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X         V      X         V      X                X                X                X                X
X    ( 1, 5)     X    ( 2, 5)     X    ( 3, 5)     X    ( 4, 5)     X    ( 5, 5)     X    ( 6, 5)     X    ( 7, 5)
X   53.852  F    X   53.852  F    X   36.477  F    X   36.477  F    X   36.477  F    X   36.477  F    X   36.477  F
X  RHS= 6.051E-04 X  RHS= 6.051E-04 X  RHS= 3.399E-04 X  RHS= 3.399E-04 X  RHS= 3.399E-04 X  RHS= 3.399E-04 X  RHS= 3.399E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01
X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02
X  CHI= 1.000E-01 X  CHI= 1.000E-01 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 6.040E-04 X  VAP= 6.040E-04 X  VAP= 2.460E-04 X  VAP= 2.460E-04 X  VAP= 2.460E-04 X  VAP= 2.460E-04 X  VAP= 2.460E-04
X  LIQ= 1.840E-04 X  LIQ= 1.840E-04 X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1, 4)     X    ( 2, 4)     X    ( 3, 4)     X    ( 4, 4)     X    ( 5, 4)     X    ( 6, 4)     X    ( 7, 4)
X   36.414  F    X   36.414  F    X   36.414  F    X   36.414  F    X   36.414  F    X   36.414  F    X   36.414  F
X  RHS= 3.479E-04 X  RHS= 3.479E-04 X  RHS= 3.479E-04 X  RHS= 3.479E-04 X  RHS= 3.479E-04 X  RHS= 3.479E-04 X  RHS= 3.479E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01
X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 2.560E-04 X  VAP= 2.560E-04 X  VAP= 2.560E-04 X  VAP= 2.560E-04 X  VAP= 2.560E-04 X  VAP= 2.560E-04 X  VAP= 2.560E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X    ( 1, 3)     X    ( 2, 3)     X    ( 3, 3)     X    ( 4, 3)     X    ( 5, 3)     X    ( 6, 3)     X    ( 7, 3)
X   36.227  F    X   36.227  F    X   36.227  F    X   36.227  F    X   36.227  F    X   36.227  F    X   36.227  F
X  RHS= 3.545E-04 X  RHS= 3.545E-04 X  RHS= 3.545E-04 X  RHS= 3.545E-04 X  RHS= 3.545E-04 X  RHS= 3.545E-04 X  RHS= 3.545E-04
      10      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0       1      0.0
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 2.650E-04 X  VAP= 2.650E-04 X  VAP= 2.650E-04 X  VAP= 2.650E-04 X  VAP= 2.650E-04 X  VAP= 2.650E-04 X  VAP= 2.650E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  0.0          , CYCLE NUMBER =     0 ,  PRESSURE ITERATION NUMBER =    0 , DT =  1.0000E-02
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XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X                X                X                X                X                X                X
X    ( 1, 2)     X    ( 2, 2)     X    ( 3, 2)     X    ( 4, 2)     X    ( 5, 2)     X    ( 6, 2)     X    ( 7, 2)
X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F
X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04
      10       0.0        1       0.0        1       0.0        1       0.0        1       0.0        1       0.0        1       0.0
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXXXXXXX    0.0   XXXX
X                X                X                X                X                X                X
X    ( 1, 1)     X    ( 2, 1)     X    ( 3, 1)     X    ( 4, 1)     X    ( 5, 1)     X    ( 6, 1)     X    ( 7, 1)
X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F   X    36.144  F
X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04
       2       0.0       10       0.0       10       0.0       10       0.0       10       0.0       10       0.0       10       0.0
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04 X  VAP= 2.750E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  0.0         , CYCLE NUMBER =     0 ,  PRESSURE ITERATION NUMBER =    0 , DT =  1.0000E-02
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XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X     ( 1,22)    X     ( 2,22)    X     ( 3,22)    X     ( 4,22)    X     ( 5,22)    X     ( 6,22)    X     ( 7,22)
X    42.756  F   X    42.756  F   X    41.924  F   X    41.973  F   X    41.987  F   X    41.980  F   X    42.021  F
X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04 X  RHS= 3.625E-04
       2       0.0      10      -0.488     10      -0.363     10      -0.225     10      -0.099     10      -0.057     10      -0.009
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0
X  VAP= 1.075E-04 X  VAP= 1.075E-04 X  VAP= 1.084E-04 X  VAP= 1.078E-04 X  VAP= 1.075E-04 X  VAP= 1.073E-04 X  VAP= 1.072E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X     ( 1,21)    X     ( 2,21)    X     ( 3,21)    X     ( 4,21)    X     ( 5,21)    X     ( 6,21)    X     ( 7,21)
X    42.756  F   X    42.756  F   X    41.924  F   X    41.973  F   X    41.987  F   X    41.980  F   X    42.021  F
X  RHS= 2.811E-04 X  RHS= 2.811E-04 X  RHS  2.723E-04 X  RHS= 2.728E-04 X  RHS= 2.730E-04 X  RHS= 2.729E-04 X  RHS= 2.734E-04
      10       0.0       1      -0.488      1      -0.363      1      -0.225      1      -0.099      1      -0.057      1      -0.009
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.075E-04 X  VAP= 1.075E-04 X  VAP= 1.084E-04 X  VAP= 1.078E-04 X  VAP= 1.075E-04 X  VAP= 1.073E-04 X  VAP= 1.072E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -0.579 XXXXXXXXX  -0.579 XXXXXXXXX   0.099 XXXXXXXXX   0.114 XXXXXXXXX   0.102 XXXXXXXXX   0.018 XXXXXXXXX   0.026 XXXX
X                X                X                X                X                X                X
X     ( 1,20)    X     ( 2,20)    X     ( 3,20)    X     ( 4,20)    X     ( 5,20)    X     ( 6,20)    X     ( 7,20)
X    42.188  F   X    42.188  F   X    41.377  F   X    41.377  F   X    41.384  F   X    41.363  F   X    41.370  F
X  RHS= 2.829E-04 X  RHS= 2.829E-04 X  RHS= 2.742E-04 X  RHS= 2.742E-04 X  RHS= 2.743E-04 X  RHS= 2.741E-04 X  RHS= 2.742E-04
      10       0.0       1      -0.272      1      -0.174      1      -0.087      1      -0.023      1       0.071      1       0.092
X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02
X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02
X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.118E-04 X  VAP= 1.118E-04 X  VAP= 1.159E-04 X  VAP= 1.154E-04 X  VAP= 1.149E-04 X  VAP= 1.146E-04 X  VAP= 1.144E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -0.941 XXXXXXXXX  -0.941 XXXXXXXXX   0.169 XXXXXXXXX   0.175 XXXXXXXXX   0.141 XXXXXXXXX   0.087 XXXXXXXXX   0.023 XXXX
X                X                X                X                X                X                X
X     ( 1,19)    X     ( 2,19)    X     ( 3,19)    X     ( 4,19)    X     ( 5,19)    X     ( 6,19)    X     ( 7,19)
X    41.446  F   X    41.446  F   X    40.829  F   X    40.677  F   X    40.649  F   X    40.670  F   X    40.670  F
X  RHS= 2.828E-04 X  RHS= 2.828E-04 X  RHS= 2.760E-04 X  RHS= 2.744E-04 X  RHS= 2.741E-04 X  RHS= 2.743E-04 X  RHS= 2.743E-04
      10       0.0       1      -0.276      1      -0.118      1       0.059      1       0.140      1       0.194      1       0.233
X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02
X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02
X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.177E-04 X  VAP= 1.177E-04 X  VAP= 1.239E-04 X  VAP= 1.236E-04 X  VAP= 1.231E-04 X  VAP= 1.228E-04 X  VAP= 1.225E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -1.301 XXXXXXXXX  -1.301 XXXXXXXXX   0.299 XXXXXXXXX   0.324 XXXXXXXXX   0.197 XXXXXXXXX   0.116 XXXXXXXXX   0.038 XXXX
X                X                X                X                X                X                X
X     ( 1,18)    X     ( 2,18)    X     ( 3,18)    X     ( 4,18)    X     ( 5,18)    X     ( 6,18)    X     ( 7,18)
X    39.824  F   X    39.824  F   X    40.441  F   X    40.399  F   X    40.351  F   X    40.330  F   X    40.323  F
X  RHS= 2.733E-04 X  RHS= 2.733E-04 X  RHS= 2.795E-04 X  RHS= 2.791E-04 X  RHS= 2.786E-04 X  RHS= 2.784E-04 X  RHS= 2.783E-04
      10       0.0       1      -0.063      1       0.067      1       0.240      1       0.337      1       0.345      1       0.341
X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02
X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02
X  CHI= 9.986E-04 X  CHI= 9.986E-04 X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.0[illegible]03
X  VAP= 1.246E-04 X  VAP= 1.246E-04 X  VAP= 1.316E-04 X  VAP= 1.318E-04 X  VAP= 1.313E-04 X  VAP= 1.308E-04 X  VAP= 1.306E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  1.[illegible]20E+02 , CYCLE NUMBER =   33 ,  PRESSURE ITERATION NUM[illegible]R =   6 , DT =  3.6603E+00
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XXXXX  -1.439 XXXXXXXXX  -1.439 XXXXXXXXX   0.401 XXXXXXXXX   0.470 XXXXXXXXX   0.269 XXXXXXXXX   0.100 XXXXXXXXX   0.011 XXXX
X              X              X              X              X              X              X
X     ( 1,17)  X     ( 2,17)  X     ( 3,17)  X     ( 4,17)  X     ( 5,17)  X     ( 6,17)  X     ( 7,17)
X   37.918  F  X   37.918  F  X   39.145  F  X   39.180  F  X   39.173  F  X   39.166  F  X   39.173  F
X  RHS= 2.612E-04 X  RHS= 2.612E-04 X  RHS= 2.735E-04 X  RHS= 2.738E-04 X  RHS= 2.738E-04 X  RHS= 2.737E-04 X  RHS= 2.738E-04
      10       0.0      1       0.441      1       0.508      1       0.538      1       0.540      1       0.499      1       0.461
X  TNU= 1.800E-01 X  TNU= 1.800E-01 X  TNU= 1.800E-01 X  TNU= 1.800E-01 X  TNU= 1.800E-01 X  TNU= 1.800E-01 X  TNU= 1.800E-01
X  TKE= 2.550E-02 X  TKE= 2.550E-02 X  TKE= 2.550E-02 X  TKE= 2.550E-02 X  TKE= 2.550E-02 X  TKE= 2.550E-02 X  TKE= 2.550E-02
X  CHI= 9.962E-04 X  CHI= 9.962E-04 X  CHI= 9.995E-04 X  CHI= 9.997E-04 X  CHI= 9.996E-04 X  CHI= 9.996E-04 X  CHI= 9.996E-04
X  VAP= 1.329E-04 X  VAP= 1.329E-04 X  VAP= 1.387E-04 X  VAP= 1.392E-04 X  VAP= 1.389E-04 X  VAP= 1.385E-04 X  VAP= 1.383E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -1.057 XXXXXXXXX  -1.057 XXXXXXXXX   0.442 XXXXXXXXX   0.477 XXXXXXXXX   0.247 XXXXXXXXX   0.037 XXXXXXXXX  -0.049 XXXX
X              X              X              X              X              X              X
X     ( 1,16)  X     ( 2,16)  X     ( 3,16)  X     ( 4,16)  X     ( 5,16)  X     ( 6,16)  X     ( 7,16)
X   36.303  F  X   36.303  F  X   38.154  F  X   38.327  F  X   38.369  F  X   38.390  F  X   38.424  F
X  RHS= 2.522E-04 X  RHS= 2.522E-04 X  RHS= 2.707E-04 X  RHS= 2.725E-04 X  RHS= 2.730E-04 X  RHS= 2.732E-04 X  RHS= 2.736E-04
      10       0.0      1       0.861      1       1.000      1       0.920      1       0.827      1       0.734      1       0.628
X  TNU= 2.560E-01 X  TNU= 2.560E-01 X  TNU= 2.560E-01 X  TNU= 2.560E-01 X  TNU= 2.560E-01 X  TNU= 2.560E-01 X  TNU= 2.560E-01
X  TKE= 2.700E-02 X  TKE= 2.700E-02 X  TKE= 2.700E-02 X  TKE= 2.700E-02 X  TKE= 2.700E-02 X  TKE= 2.700E-02 X  TKE= 2.700E-02
X  CHI= 9.950E-04 X  CHI= 9.950E-04 X  CHI= 9.989E-04 X  CHI= 9.992E-04 X  CHI= 9.993E-04 X  CHI= 9.993E-04 X  CHI= 9.993E-04
X  VAP= 1.437E-04 X  VAP= 1.437E-04 X  VAP= 1.467E-04 X  VAP= 1.466E-04 X  VAP= 1.461E-04 X  VAP= 1.455E-04 X  VAP= 1.452E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -0.237 XXXXXXXXX  -0.237 XXXXXXXXX   0.559 XXXXXXXXX   0.375 XXXXXXXXX   0.134 XXXXXXXXX  -0.076 XXXXXXXXX  -0.172 XXXX
X              X              X              X              X              X              X
X     ( 1,15)  X     ( 2,15)  X     ( 3,15)  X     ( 4,15)  X     ( 5,15)  X     ( 6,15)  X     ( 7,15)
X   35.416  F  X   35.416  F  X   37.343  F  X   37.558  F  X   37.710  F  X   37.800  F  X   37.856  F
X  RHS= 2.500E-04 X  RHS= 2.500E-04 X  RHS= 2.693E-04 X  RHS= 2.716E-04 X  RHS= 2.732E-04 X  RHS= 2.742E-04 X  RHS= 2.748E-04
      10       0.0      1       1.106      1       1.407      1       1.332      1       1.164      1       0.995      1       0.809
X  TNU= 3.270E-01 X  TNU= 3.270E-01 X  TNU= 3.270E-01 X  TNU= 3.270E-01 X  TNU= 3.270E-01 X  TNU= 3.270E-01 X  TNU= 3.270E-01
X  TKE= 2.770E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02
X  CHI= 1.026E-03 X  CHI= 1.026E-03 X  CHI= 1.001E-03 X  CHI= 9.987E-04 X  CHI= 9.988E-04 X  CHI= 9.989E-04 X  CHI= 9.990E-04
X  VAP= 1.604E-04 X  VAP= 1.604E-04 X  VAP= 1.592E-04 X  VAP= 1.580E-04 X  VAP= 1.573E-04 X  VAP= 1.569E-04 X  VAP= 1.567E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.848 XXXXXXXXX   0.848 XXXXXXXXX   0.844 XXXXXXXXX   0.285 XXXXXXXXX  -0.050 XXXXXXXXX  -0.260 XXXXXXXXX  -0.374 XXXX
X              X              X              X              X              X              X
X     ( 1,14)  X     ( 2,14)  X     ( 3,14)  X     ( 4,14)  X     ( 5,14)  X     ( 6,14)  X     ( 7,14)
X   34.903  F  X   34.903  F  X   36.574  F  X   36.747  F  X   36.782  F  X   36.816  F  X   36.851  F
X  RHS= 2.517E-04 X  RHS= 2.517E-04 X  RHS= 2.687E-04 X  RHS= 2.706E-04 X  RHS= 2.710E-04 X  RHS= 2.714E-04 X  RHS= 2.717E-04
      10       0.0      1       1.453      1       1.784      1       1.688      1       1.409      1       1.126      1       0.920
X  TNU= 4.085E-01 X  TNU= 4.085E-01 X  TNU= 3.880E-01 X  TNU= 3.880E-01 X  TNU= 3.880E-01 X  TNU= 3.880E-01 X  TNU= 3.880E-01
X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02
X  CHI= 1.661E-03 X  CHI= 1.661E-03 X  CHI= 1.070E-03 X  CHI= 1.002E-03 X  CHI= 9.987E-04 X  CHI= 9.986E-04 X  CHI= 9.986E-04
X  VAP= 1.769E-04 X  VAP= 1.769E-04 X  VAP= 1.692E-04 X  VAP= 1.664E-04 X  VAP= 1.652E-04 X  VAP= 1.647E-04 X  VAP= 1.644E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   2.297 XXXXXXXXX   2.297 XXXXXXXXX   1.165 XXXXXXXXX   0.179 XXXXXXXXX  -0.339 XXXXXXXXX  -0.552 XXXXXXXXX  -0.589 XXXX
X         V20  X         V20  X              X              X              X              X
X     ( 1,13)  X     ( 2,13)  X     ( 3,13)  X     ( 4,13)  X     ( 5,13)  X     ( 6,13)  X     ( 7,13)
X   35.077  F  X   35.077  F  X   36.220  F  X   36.539  F  X   36.636  F  X   36.705  F  X   36.768  F
X  RHS= 2.591E-04 X  RHS= 2.591E-04 X  RHS= 2.721E-04 X  RHS= 2.758E-04 X  RHS= 2.769E-04 X  RHS= 2.776E-04 X  RHS= 2.783E-04
      10       0.0      1       2.283      1       2.517      1       2.132      1       1.640      1       1.228      1       0.931
X  TNU= 5.966E-01 X  TNU= 5.966E-01 X  TNU= 4.552E-01 X  TNU= 4.350E-01 X  TNU= 4.350E-01 X  TNU= 4.350E-01 X  TNU= 4.350E-01
X  TKE= 3.782E-02 X  TKE= 3.782E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02
X  CHI= 6.000E-03 X  CHI= 6.000E-03 X  CHI= 1.850E-03 X  CHI= 1.073E-03 X  CHI= 1.003E-03 X  CHI= 9.990E-04 X  CHI= 9.989E-04
X  VAP= 2.187E-04 X  VAP= 2.187E-04 X  VAP= 1.845E-04 X  VAP= 1.758E-04 X  VAP= 1.739E-04 X  VAP= 1.733E-04 X  VAP= 1.730E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  1.0220E+02 , CYCLE NUMBER =   33 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.6603E+00
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XXXXX    4.591 XXXXXXXXX    4.591 XXXXXXXXX    1.394 XXXXXXXXX   -0.211 XXXXXXXXX   -0.836 XXXXXXXXX   -0.969 XXXXXXXXX   -0.891 XXXX
X           V             X          V         X                  X                  X                  X                  X
X      ( 1,12)            X      ( 2,12)       X      ( 3,12)     X      ( 4,12)     X      ( 5,12)     X      ( 6,12)     X      ( 7,12)
X    36.629   F           X    36.629   F      X    36.089   F    X    36.179   F    X    36.220   F    X    36.310   F    X    36.387   F
X  RHS= 2.803E-04         X  RHS= 2.803E-04    X  RHS= 2.771E-04  X  RHS= 2.793E-04  X  RHS= 2.800E-04  X  RHS= 2.810E-04  X  RHS= 2.818E-04
      10          0.0          1        3.108        1        3.305       1        2.609       1        1.852       1        1.314       1        0.918
X  TNU= 8.385E-01         X  TNU= 8.385E-01    X  TNU= 6.035E-01  X  TNU= 4.849E-01  X  TNU= 4.770E-01  X  TNU= 4.770E-01  X  TNU= 4.770E-01
X  TKE= 6.048E-02         X  TKE= 6.048E-02    X  TKE= 3.611E-02  X  TKE= 3.030E-02  X  TKE= 3.030E-02  X  TKE= 3.030E-02  X  TKE= 3.030E-02
X  CHI= 1.625E-02         X  CHI= 1.625E-02    X  CHI= 5.529E-03  X  CHI= 1.732E-03  X  CHI= 1.066E-03  X  CHI= 1.002E-03  X  CHI= 9.990E-04
X  VAP= 2.803E-04         X  VAP= 2.803E-04    X  VAP= 2.185E-04  X  VAP= 1.874E-04  X  VAP= 1.804E-04  X  VAP= 1.791E-04  X  VAP= 1.788E-04
X  LIQ= 1.955E-05         X  LIQ= 1.955E-05    X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX    7.727 XXXXXXXXX    7.727 XXXXXXXXX    1.590 XXXXXXXXX   -0.908 XXXXXXXXX   -1.594 XXXXXXXXX   -1.508 XXXXXXXXX   -1.287 XXXX
X           V             X          V         X         V10      X                  X                  X                  X
X      ( 1,11)            X      ( 2,11)       X      ( 3,11)     X      ( 4,11)     X      ( 5,11)     X      ( 6,11)     X      ( 7,11)
X    38.417   F           X    38.417   F      X    36.511   F    X    36.352   F    X    36.165   F    X    36.165   F    X    36.206   F
X  RHS= 3.073E-04         X  RHS= 3.073E-04    X  RHS= 2.874E-04  X  RHS= 2.881E-04  X  RHS= 2.869E-04  X  RHS= 2.870E-04  X  RHS= 2.875E-04
      10          0.0          1        2.619        1        3.195       1        2.601       1        1.794       1        1.189       1        0.784
X  TNU= 8.434E-01         X  TNU= 8.434E-01    X  TNU= 7.513E-01  X  TNU= 5.605E-01  X  TNU= 5.150E-01  X  TNU= 5.150E-01  X  TNU= 5.150E-01
X  TKE= 6.229E-02         X  TKE= 6.229E-02    X  TKE= 4.742E-02  X  TKE= 3.068E-02  X  TKE= 3.050E-02  X  TKE= 3.050E-02  X  TKE= 3.050E-02
X  CHI= 2.299E-02         X  CHI= 2.299E-02    X  CHI= 1.185E-02  X  CHI= 3.852E-03  X  CHI= 1.419E-03  X  CHI= 1.031E-03  X  CHI= 1.000E-03
X  VAP= 3.072E-04         X  VAP= 3.072E-04    X  VAP= 2.696E-04  X  VAP= 2.098E-04  X  VAP= 1.905E-04  X  VAP= 1.868E-04  X  VAP= 1.864E-04
X  LIQ= 5.075E-05         X  LIQ= 5.075E-05    X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX   10.390 XXXXXXXXX   10.390 XXXXXXXXX    2.170 XXXXXXXXX   -1.497 XXXXXXXXX   -2.398 XXXXXXXXX   -2.109 XXXXXXXXX   -1.689 XXXX
X           V             X          V         X         V        X                  X                  X                  X
X      ( 1,10)            X      ( 2,10)       X      ( 3,10)     X      ( 4,10)     X      ( 5,10)     X      ( 6,10)     X      ( 7,10)
X    38.161   F           X    38.161   F      X    37.274   F    X    36.691   F    X    36.317   F    X    36.220   F    X    36.213   F
X  RHS= 3.127E-04         X  RHS= 3.127E-04    X  RHS= 3.028E-04  X  RHS= 2.993E-04  X  RHS= 2.964E-04  X  RHS= 2.956E-04  X  RHS= 2.955E-04
      10          0.0          1        0.708        1        1.832       1        1.688       1        1.195       1        0.755       1        0.467
X  TNU= 7.182E-01         X  TNU= 7.182E-01    X  TNU= 8.222E-01  X  TNU= 6.101E-01  X  TNU= 5.530E-01  X  TNU= 5.530E-01  X  TNU= 5.530E-01
X  TKE= 4.860E-02         X  TKE= 4.860E-02    X  TKE= 5.274E-02  X  TKE= 3.143E-02  X  TKE= 3.060E-02  X  TKE= 3.060E-02  X  TKE= 3.060E-02
X  CHI= 2.135E-02         X  CHI= 2.135E-02    X  CHI= 1.634E-02  X  CHI= 6.194E-03  X  CHI= 1.994E-03  X  CHI= 1.098E-03  X  CHI= 1.004E-03
X  VAP= 3.126E-04         X  VAP= 3.126E-04    X  VAP= 3.028E-04  X  VAP= 2.298E-04  X  VAP= 1.987E-04  X  VAP= 1.917E-04  X  VAP= 1.910E-04
X  LIQ= 4.396E-05         X  LIQ= 4.396E-05    X  LIQ= 1.165E-06  X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX   11.155 XXXXXXXXX   11.155 XXXXXXXXX    3.304 XXXXXXXXX   -1.632 XXXXXXXXX   -2.883 XXXXXXXXX   -2.541 XXXXXXXXX   -1.969 XXXX
X           V             X          V         X         V        X                  X                  X                  X
X      ( 1, 9)            X      ( 2, 9)       X      ( 3, 9)     X      ( 4, 9)     X      ( 5, 9)     X      ( 6, 9)     X      ( 7, 9)
X    37.412   F           X    37.412   F      X    37.884   F    X    37.260   F    X    36.691   F    X    36.470   F    X    36.400   F
X  RHS= 3.125E-04         X  RHS= 3.125E-04    X  RHS= 3.178E-04  X  RHS= 3.140E-04  X  RHS= 3.088E-04  X  RHS= 3.065E-04  X  RHS= 3.057E-04
      10          0.0          1       -1.099        1        0.024       1        0.095       1        0.049       1        0.013       1       -0.004
X  TNU= 6.833E-01         X  TNU= 6.833E-01    X  TNU= 8.137E-01  X  TNU= 5.995E-01  X  TNU= 5.650E-01  X  TNU= 5.650E-01  X  TNU= 5.650E-01
X  TKE= 4.535E-02         X  TKE= 4.535E-02    X  TKE= 5.195E-02  X  TKE= 3.090E-02  X  TKE= 3.090E-02  X  TKE= 3.090E-02  X  TKE= 3.090E-02
X  CHI= 1.672E-02         X  CHI= 1.672E-02    X  CHI= 1.799E-02  X  CHI= 6.671E-03  X  CHI= 1.928E-03  X  CHI= 1.066E-03  X  CHI= 1.002E-03
X  VAP= 3.124E-04         X  VAP= 3.124E-04    X  VAP= 3.193E-04  X  VAP= 2.383E-04  X  VAP= 2.046E-04  X  VAP= 1.987E-04  X  VAP= 1.991E-04
X  LIQ= 1.663E-05         X  LIQ= 1.663E-05    X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX   10.121 XXXXXXXXX   10.121 XXXXXXXXX    4.442 XXXXXXXXX   -1.547 XXXXXXXXX   -2.917 XXXXXXXXX   -2.565 XXXXXXXXX   -1.975 XXXX
X          V10            X         V10        X         V10      X                  X                  X                  X
X      ( 1, 8)            X      ( 2, 8)       X      ( 3, 8)     X      ( 4, 8)     X      ( 5, 8)     X      ( 6, 8)     X      ( 7, 8)
X    37.544   F           X    37.544   F      X    37.322   F    X    37.274   F    X    36.809   F    X    36.601   F    X    36.560   F
X  RHS= 3.233E-04         X  RHS= 3.233E-04    X  RHS= 3.209E-04  X  RHS= 3.231E-04  X  RHS= 3.187E-04  X  RHS= 3.163E-04  X  RHS= 3.157E-04
      10          0.0          1       -1.409        1       -1.897       1       -1.574       1       -1.109       1       -0.715       1       -0.457
X  TNU= 6.585E-01         X  TNU= 6.585E-01    X  TNU= 6.873E-01  X  TNU= 5.585E-01  X  TNU= 5.400E-01  X  TNU= 5.400E-01  X  TNU= 5.400E-01
X  TKE= 4.423E-02         X  TKE= 4.423E-02    X  TKE= 4.201E-02  X  TKE= 3.120E-02  X  TKE= 3.120E-02  X  TKE= 3.120E-02  X  TKE= 3.120E-02
X  CHI= 1.202E-02         X  CHI= 1.202E-02    X  CHI= 1.402E-02  X  CHI= 5.453E-03  X  CHI= 1.527E-03  X  CHI= 1.024E-03  X  CHI= 1.000E-03
X  VAP= 3.039E-04         X  VAP= 3.039E-04    X  VAP= 2.985E-04  X  VAP= 2.378E-04  X  VAP= 2.113E-04  X  VAP= 2.094E-04  X  VAP= 2.115E-04
X  LIQ= 0.0               X  LIQ= 0.0          X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
TIME=  1.0220E+02 , CYCLE NUMBER =    33 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.6603E+00
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XXXXX   8.781 XXXXXXXXX   8.781 XXXXXXXXX   3.974 XXXXXXXXX  -1.206 XXXXXXXXX  -2.436 XXXXXXXXX  -2.155 XXXXXXXXX  -1.703 XXXX
X           V20    X            V20    X            V20    X                  X                  X                  X
X     ( 1, 7)      X     ( 2, 7)      X     ( 3, 7)      X     ( 4, 7)      X     ( 5, 7)      X     ( 6, 7)      X     ( 7, 7)
X    38.729  F     X    38.729  F     X    36.594  F     X    36.643  F     X    36.643  F     X    36.733  F     X    36.809  F
X  RHS= 3.485E-04 X  RHS= 3.485E-04 X  RHS= 3.223E-04 X  RHS= 3.244E-04 X  RHS= 3.250E-04 X  RHS= 3.261E-04 X  RHS= 3.269E-04
     10       0.0       1      -1.419       1      -2.991       1      -2.471       1      -1.716       1      -1.126       1      -0.771
X  TNU= 6.004E-01 X  TNU= 6.004E-01 X  TNU= 5.883E-01 X  TNU= 5.049E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01
X  TKE= 4.032E-02 X  TKE= 4.032E-02 X  TKE= 3.716E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 7.358E-03 X  CHI= 7.358E-03 X  CHI= 7.928E-03 X  CHI= 3.544E-03 X  CHI= 1.229E-03 X  CHI= 1.006E-03 X  CHI= 1.000E-03
X  VAP= 2.808E-04 X  VAP= 2.808E-04 X  VAP= 2.661E-04 X  VAP= 2.344E-04 X  VAP= 2.200E-04 X  VAP= 2.209E-04 X  VAP= 2.231E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   7.429 XXXXXXXXX   7.429 XXXXXXXXX   2.423 XXXXXXXXX  -0.665 XXXXXXXXX  -1.661 XXXXXXXXX  -1.548 XXXXXXXXX  -1.330 XXXX
X                  X                  X                  X                  X                  X                  X
X     ( 1, 6)      X     ( 2, 6)      X     ( 3, 6)      X     ( 4, 6)      X     ( 5, 6)      X     ( 6, 6)      X     ( 7, 6)
X    39.748  F     X    39.748  F     X    36.608  F     X    36.899  F     X    36.927  F     X    36.955  F     X    36.934  F
X  RHS= 3.727E-04 X  RHS= 3.727E-04 X  RHS= 3.323E-04 X  RHS= 3.366E-04 X  RHS= 3.372E-04 X  RHS= 3.375E-04 X  RHS= 3.371E-04
     10       0.0       1      -1.145       1      -2.772       1      -2.519       1      -1.873       1      -1.392       1      -1.074
X  TNU= 5.272E-01 X  TNU= 5.272E-01 X  TNU= 5.057E-01 X  TNU= 4.273E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01
X  TKE= 3.511E-02 X  TKE= 3.511E-02 X  TKE= 3.428E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02
X  CHI= 3.713E-03 X  CHI= 3.713E-03 X  CHI= 3.445E-03 X  CHI= 2.006E-03 X  CHI= 1.067E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03
X  VAP= 2.665E-04 X  VAP= 2.665E-04 X  VAP= 2.475E-04 X  VAP= 2.352E-04 X  VAP= 2.299E-04 X  VAP= 2.314E-04 X  VAP= 2.330E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   6.351 XXXXXXXXX   6.351 XXXXXXXXX   0.814 XXXXXXXXX  -0.393 XXXXXXXXX  -0.995 XXXXXXXXX  -1.048 XXXXXXXXX  -0.993 XXXX
X                  X                  X                  X                  X                  X                  X
X     ( 1, 5)      X     ( 2, 5)      X     ( 3, 5)      X     ( 4, 5)      X     ( 5, 5)      X     ( 6, 5)      X     ( 7, 5)
X    40.372  F     X    40.372  F     X    36.546  F     X    36.629  F     X    36.671  F     X    36.650  F     X    36.650  F
X  RHS= 3.920E-04 X  RHS= 3.920E-04 X  RHS= 3.407E-04 X  RHS= 3.421E-04 X  RHS= 3.426E-04 X  RHS= 3.423E-04 X  RHS= 3.423E-04
     10       0.0       1      -0.878       1      -2.010       1      -2.203       1      -1.920       1      -1.580       1      -1.247
X  TNU= 4.589E-01 X  TNU= 4.589E-01 X  TNU= 4.308E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01
X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02
X  CHI= 1.821E-03 X  CHI= 1.821E-03 X  CHI= 1.757E-03 X  CHI= 1.184E-03 X  CHI= 1.010E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 2.638E-04 X  VAP= 2.638E-04 X  VAP= 2.467E-04 X  VAP= 2.412E-04 X  VAP= 2.401E-04 X  VAP= 2.411E-04 X  VAP= 2.420E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   5.536 XXXXXXXXX   5.536 XXXXXXXXX  -0.294 XXXXXXXXX  -0.565 XXXXXXXXX  -0.694 XXXXXXXXX  -0.690 XXXXXXXXX  -0.643 XXXX
X                  X                  X                  X                  X                  X                  X
X     ( 1, 4)      X     ( 2, 4)      X     ( 3, 4)      X     ( 4, 4)      X     ( 5, 4)      X     ( 6, 4)      X     ( 7, 4)
X    39.984  F     X    39.984  F     X    36.879  F     X    36.497  F     X    36.470  F     X    36.574  F     X    36.712  F
X  RHS= 3.967E-04 X  RHS= 3.967E-04 X  RHS= 3.540E-04 X  RHS= 3.491E-04 X  RHS= 3.488E-04 X  RHS= 3.501E-04 X  RHS= 3.519E-04
     10       0.0       1      -1.275       1      -1.556       1      -1.635       1      -1.493       1      -1.261       1      -1.020
X  TNU= 4.184E-01 X  TNU= 4.184E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01
X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02
X  CHI= 1.025E-03 X  CHI= 1.025E-03 X  CHI= 1.044E-03 X  CHI= 1.017E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03 X  CHI= 1.001E-03
X  VAP= 2.660E-04 X  VAP= 2.660E-04 X  VAP= 2.547E-04 X  VAP= 2.521E-04 X  VAP= 2.516E-04 X  VAP= 2.521E-04 X  VAP= 2.527E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   4.310 XXXXXXXXX   4.310 XXXXXXXXX  -0.550 XXXXXXXXX  -0.621 XXXXXXXXX  -0.531 XXXXXXXXX  -0.438 XXXXXXXXX  -0.384 XXXX
X                  X                  X                  X                  X                  X                  X
X     ( 1, 3)      X     ( 2, 3)      X     ( 3, 3)      X     ( 4, 3)      X     ( 5, 3)      X     ( 6, 3)      X     ( 7, 3)
X    39.388  F     X    39.388  F     X    37.752  F     X    37.551  F     X    37.405  F     X    37.281  F     X    37.135  F
X  RHS= 3.983E-04 X  RHS= 3.983E-04 X  RHS= 3.752E-04 X  RHS= 3.725E-04 X  RHS= 3.705E-04 X  RHS= 3.688E-04 X  RHS= 3.668E-04
     10       0.0       1      -1.759       1      -1.633       1      -1.384       1      -1.184       1      -1.031       1      -0.912
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02
X  CHI= 1.007E-03 X  CHI= 1.007E-03 X  CHI= 1.005E-03 X  CHI= 1.004E-03 X  CHI= 1.002E-03 X  CHI= 1.002E-03 X  CHI= 1.002E-03
X  VAP= 2.715E-04 X  VAP= 2.715E-04 X  VAP= 2.651E-04 X  VAP= 2.638E-04 X  VAP= 2.633E-04 X  VAP= 2.633E-04 X  VAP= 2.635E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  1.0220E+02 , CYCLE NUMBER =   33 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.6603E+00
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XXXXX   2.584 XXXXXXXXX   2.584 XXXXXXXXX  -0.403 XXXXXXXXX  -0.353 XXXXXXXXX  -0.310 XXXXXXXXX  -0.266 XXXXXXXXX  -0.245 XXXX
X               X               X               X               X               X               X
X    ( 1, 2)    X    ( 2, 2)    X    ( 3, 2)    X    ( 4, 2)    X    ( 5, 2)    X    ( 6, 2)    X    ( 7, 2)
X   38.958  F   X   38.958  F   X   38.265  F   X   38.175  F   X   38.029  F   X   37.877  F   X   37.752  F
X  RHS= 4.024E-04 X RHS= 4.024E-04 X RHS= 3.922E-04 X RHS= 3.909E-04 X RHS= 3.889E-04 X RHS= 3.867E-04 X RHS= 3.849E-04
      10        0.0      1       -2.598      1       -2.218      1       -1.891      1       -1.611      1       -1.376      1       -1.164
X  TNU= 4.260E-01 X TNU= 4.260E-01 X TNU= 4.170E-01 X TNU= 4.170E-01 X TNU= 4.170E-01 X TNU= 4.170E-01 X TNU= 4.170E-01
X  TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02
X  CHI= 1.006E-03 X CHI= 1.006E-03 X CHI= 1.004E-03 X CHI= 1.004E-03 X CHI= 1.004E-03 X CHI= 1.004E-03 X CHI= 1.003E-03
X  VAP= 2.764E-04 X VAP= 2.764E-04 X VAP= 2.753E-04 X VAP= 2.752E-04 X VAP= 2.749E-04 X VAP= 2.748E-04 X VAP= 2.748E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X               X               X               X               X               X               X
X    ( 1, 1)    X    ( 2, 1)    X    ( 3, 1)    X    ( 4, 1)    X    ( 5, 1)    X    ( 6, 1)    X    ( 7, 1)
X   38.958  F   X   38.958  F   X   38.265  F   X   38.175  F   X   38.029  F   X   37.877  F   X   37.752  F
X  RHS= 4.024E-04 X RHS= 4.024E-04 X RHS= 3.922E-04 X RHS= 3.909E-04 X RHS= 3.889E-04 X RHS= 3.867E-04 X RHS= 3.849E-04
       2       2.598     10        2.598     10        2.218     10        1.891     10        1.611     10        1.376     10        1.164
X  TNU= 4.260E-01 X TNU= 4.260E-01 X TNU= 4.170E-01 X TNU= 4.170E-01 X TNU= 4.170E-01 X TNU= 4.170E-01 X TNU= 4.170E-01
X  TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02 X TKE= 4.080E-02
X  CHI= 1.006E-03 X CHI= 1.006E-03 X CHI= 1.004E-03 X CHI= 1.004E-03 X CHI= 1.004E-03 X CHI= 1.004E-03 X CHI= 1.003E-03
X  VAP= 2.764E-04 X VAP= 2.764E-04 X VAP= 2.753E-04 X VAP= 2.752E-04 X VAP= 2.749E-04 X VAP= 2.748E-04 X VAP= 2.748E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  1.0220E+02 , CYCLE NUMBER =    33 ,  PRESSURE ITERATION NUMBER =    6 , DT =  3.6603E+00
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PLUME CENTER AT 1545.10 FEET. PLUME SPEED IS   14.55  DOWNWIND DISTANCE IS 1383.
   TOTAL  ENERGY   ON MESH IS   0.73843E+08
TIME=  1.0220E+02 , CYCLE NUMBER =    33 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.6603E+00 , MAX DIVERGENCE =  5.5096E-04
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XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X     ( 1,22)    X     ( 2,22)    X     ( 3,22)    X     ( 4,22)    X     ( 5,22)    X     ( 6,22)    X     ( 7,22)
X   43.158  F    X   43.158  F    X   41.813  F    X   41.848  F    X   41.883  F    X   41.903  F    X   41.945  F
X  RHS= 3.788E-04 X  RHS= 3.784E-04 X  RHS= 3.782E-04 X  RHS= 3.781E-04 X  RHS= 3.782E-04 X  RHS= 3.784E-04 X  RHS= 3.625E-04
      2      0.0       10     -0.876      10     -0.714      10     -0.620      10     -0.513      10     -0.492      10     -0.393
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0
X  VAP= 1.082E-04 X  VAP= 1.082E-04 X  VAP= 1.091E-04 X  VAP= 1.085E-04 X  VAP= 1.081E-04 X  VAP= 1.075E-04 X  VAP= 1.076E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X     ( 1,21)    X     ( 2,21)    X     ( 3,21)    X     ( 4,21)    X     ( 5,21)    X     ( 6,21)    X     ( 7,21)
X   43.158  F    X   43.158  F    X   41.813  F    X   41.848  F    X   41.883  F    X   41.903  F    X   41.945  F
X  RHS= 2.854E-04 X  RHS= 2.854E-04 X  RHS= 2.711E-04 X  RHS= 2.715E-04 X  RHS= 2.719E-04 X  RHS= 2.721E-04 X  RHS= 2.726E-04
     10      0.0        1     -0.876       1     -0.714       1     -0.620       1     -0.513       1     -0.492       1     -0.393
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 1.002E-03 X  CHI= 1.002E-03 X  CHI= 1.000E-03 X  CHI= 9.999E-04 X  CHI= 9.999E-04 X  CHI= 9.999E-04 X  CHI= 9.999E-04
X  VAP= 1.082E-04 X  VAP= 1.082E-04 X  VAP= 1.091E-04 X  VAP= 1.085E-04 X  VAP= 1.081E-04 X  VAP= 1.075E-04 X  VAP= 1.076E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -0.893 XXXXXXXXX  -0.893 XXXXXXXXX   0.154 XXXXXXXXX   0.087 XXXXXXXXX   0.100 XXXXXXXXX   0.014 XXXXXXXXX   0.092 XXXX
X                X                X                X                X                X                X
X     ( 1,20)    X     ( 2,20)    X     ( 3,20)    X     ( 4,20)    X     ( 5,20)    X     ( 6,20)    X     ( 7,20)
X   42.694  F    X   42.694  F    X   41.266  F    X   41.245  F    X   41.245  F    X   41.245  F    X   41.280  F
X  RHS= 2.884E-04 X  RHS= 2.884E-04 X  RHS= 2.730E-04 X  RHS= 2.728E-04 X  RHS= 2.728E-04 X  RHS= 2.728E-04 X  RHS= 2.732E-04
     10      0.0        1     -0.174       1     -0.200       1     -0.261       1     -0.280       1     -0.167       1     -0.175
X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02
X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02
X  CHI= 1.002E-03 X  CHI= 1.002E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.110E-04 X  VAP= 1.110E-04 X  VAP= 1.170E-04 X  VAP= 1.164E-04 X  VAP= 1.159E-04 X  VAP= 1.155E-04 X  VAP= 1.150E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -1.084 XXXXXXXXX  -1.084 XXXXXXXXX   0.122 XXXXXXXXX   0.021 XXXXXXXXX   0.074 XXXXXXXXX   0.122 XXXXXXXXX   0.078 XXXX
X                X                X                X                X                X                X
X     ( 1,19)    X     ( 2,19)    X     ( 3,19)    X     ( 4,19)    X     ( 5,19)    X     ( 6,19)    X     ( 7,19)
X   41.779  F    X   41.779  F    X   40.781  F    X   40.600  F    X   40.587  F    X   40.621  F    X   40.628  F
X  RHS= 2.864E-04 X  RHS= 2.864E-04 X  RHS= 2.754E-04 X  RHS= 2.735E-04 X  RHS= 2.734E-04 X  RHS= 2.738E-04 X  RHS= 2.739E-04
     10      0.0        1     -0.071       1     -0.051       1      0.041       1      0.077       1      0.142       1      0.194
X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02
X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02
X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.155E-04 X  VAP= 1.155E-04 X  VAP= 1.255E-04 X  VAP= 1.257E-04 X  VAP= 1.247E-04 X  VAP= 1.241E-04 X  VAP= 1.234E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -1.179 XXXXXXXXX  -1.179 XXXXXXXXX   0.138 XXXXXXXXX   0.108 XXXXXXXXX   0.104 XXXXXXXXX   0.182 XXXXXXXXX   0.124 XXXX
X                X                X                X                X                X                X
X     ( 1,18)    X     ( 2,18)    X     ( 3,18)    X     ( 4,18)    X     ( 5,18)    X     ( 6,18)    X     ( 7,18)
X   40.261  F    X   40.261  F    X   40.018  F    X   39.914  F    X   39.956  F    X   40.032  F    X   40.088  F
X  RHS= 2.781E-04 X  RHS= 2.781E-04 X  RHS= 2.750E-04 X  RHS= 2.739E-04 X  RHS= 2.743E-04 X  RHS= 2.752E-04 X  RHS= 2.758E-04
     10      0.0        1      0.254       1      0.262       1      0.434       1      0.554       1      0.539       1      0.527
X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.3[illegible]-02
X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02
X  CHI= 9.988E-04 X  CHI= 9.988E-04 X  CHI= 1.001E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 1.201E-04 X  VAP= 1.201E-04 X  VAP= 1.333E-04 X  VAP= 1.3[illegible]7E-04 X  VAP= 1.336E-04 X  VAP= 1.324E-04 X  VAP= 1.315[illegible]-04
X  LIQ= [illegible]  X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.[illegible]    X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  2[illegible]66E+02 , CYCLE NUMBER =    62 ,  PRESSURE ITERATION NU[illegible]R =    4 , DT =  3.1448E+00
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XXXXX  -0.958 XXXXXXXXX  -0.958 XXXXXXXXX   0.144 XXXXXXXXX   0.276 XXXXXXXXX   0.219 XXXXXXXXX   0.162 XXXXXXXXX   0.105 XXXX
X               X               X               X               X               X               X
X    ( 1,17)    X    ( 2,17)    X    ( 3,17)    X    ( 4,17)    X    ( 5,17)    X    ( 6,17)    X    ( 7,17)
X   38.698  F   X   38.698  F   X   38.861  F   X   38.743  F   X   38.805  F   X   38.902  F   X   38.965  F
X RHS= 2.693E-04 X RHS= 2.693E-04 X RHS= 2.706E-04 X RHS= 2.692E-04 X RHS= 2.698E-04 X RHS= 2.709E-04 X RHS= 2.716E-04
     10       0.0      1       1.279      1       1.288      1       1.201      1       1.133      1       1.008      1       0.864
X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01 X TNU= 1.800E-01
X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02 X TKE= 2.550E-02
X CHI= 1.015E-03 X CHI= 1.015E-03 X CHI= 1.018E-03 X CHI= 1.009E-03 X CHI= 1.001E-03 X CHI= 9.996E-04 X CHI= 9.994E-04
X VAP= 1.257E-04 X VAP= 1.257E-04 X VAP= 1.378E-04 X VAP= 1.420E-04 X VAP= 1.415E-04 X VAP= 1.400E-04 X VAP= 1.390E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   0.268 XXXXXXXXX   0.268 XXXXXXXXX   0.149 XXXXXXXXX   0.185 XXXXXXXXX   0.145 XXXXXXXXX   0.030 XXXXXXXXX  -0.045 XXXX
X               X               X               X               X               X               X
X    ( 1,16)    X    ( 2,16)    X    ( 3,16)    X    ( 4,16)    X    ( 5,16)    X    ( 6,16)    X    ( 7,16)
X   36.782  F   X   36.782  F   X   37.690  F   X   37.780  F   X   38.029  F   X   38.216  F   X   38.313  F
X RHS= 2.559E-04 X RHS= 2.559E-04 X RHS= 2.657E-04 X RHS= 2.667E-04 X RHS= 2.693E-04 X RHS= 2.713E-04 X RHS= 2.724E-04
     10       0.0      1       2.989      1       3.290      1       2.686      1       2.075      1       1.643      1       1.308
X TNU= 4.891E-01 X TNU= 4.891E-01 X TNU= 2.865E-01 X TNU= 2.560E-01 X TNU= 2.560E-01 X TNU= 2.560E-01 X TNU= 2.560E-01
X TKE= 3.944E-02 X TKE= 3.944E-02 X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02 X TKE= 2.700E-02
X CHI= 3.556E-03 X CHI= 3.556E-03 X CHI= 1.734E-03 X CHI= 1.185E-03 X CHI= 1.038E-03 X CHI= 1.004E-03 X CHI= 9.997E-04
X VAP= 1.713E-04 X VAP= 1.713E-04 X VAP= 1.532E-04 X VAP= 1.504E-04 X VAP= 1.492E-04 X VAP= 1.473E-04 X VAP= 1.459E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   3.193 XXXXXXXXX   3.193 XXXXXXXXX   0.437 XXXXXXXXX  -0.431 XXXXXXXXX  -0.478 XXXXXXXXX  -0.413 XXXXXXXXX  -0.390 XXXX
X       V       X       V       X      V20      X               X               X               X
X    ( 1,15)    X    ( 2,15)    X    ( 3,15)    X    ( 4,15)    X    ( 5,15)    X    ( 6,15)    X    ( 7,15)
X   36.581  F   X   36.581  F   X   37.003  F   X   36.913  F   X   37.087  F   X   37.392  F   X   37.627  F
X RHS= 2.578E-04 X RHS= 2.578E-04 X RHS= 2.632E-04 X RHS= 2.638E-04 X RHS= 2.663E-04 X RHS= 2.698E-04 X RHS= 2.724E-04
     10       0.0      1       3.814      1       5.045      1       4.594      1       3.581      1       2.634      1       1.920
X TNU= 1.145E+00 X TNU= 1.145E+00 X TNU= 7.737E-01 X TNU= 4.731E-01 X TNU= 3.449E-01 X TNU= 3.270E-01 X TNU= 3.270E-01
X TKE= 8.819E-02 X TKE= 8.819E-02 X TKE= 5.084E-02 X TKE= 3.007E-02 X TKE= 2.770E-02 X TKE= 2.770E-02 X TKE= 2.770E-02
X CHI= 1.050E-02 X CHI= 1.050E-02 X CHI= 7.301E-03 X CHI= 3.763E-03 X CHI= 1.863E-03 X CHI= 1.173E-03 X CHI= 1.021E-03
X VAP= 2.579E-04 X VAP= 2.579E-04 X VAP= 2.284E-04 X VAP= 1.894E-04 X VAP= 1.686E-04 X VAP= 1.600E-04 X VAP= 1.570E-04
X LIQ= 1.463E-05 X LIQ= 1.463E-05 X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   6.934 XXXXXXXXX   6.934 XXXXXXXXX   1.651 XXXXXXXXX  -0.897 XXXXXXXXX  -1.506 XXXXXXXXX  -1.374 XXXXXXXXX  -1.118 XXXX
X       V       X       V       X       V       X      V20      X               X               X
X    ( 1,14)    X    ( 2,14)    X    ( 3,14)    X    ( 4,14)    X    ( 5,14)    X    ( 6,14)    X    ( 7,14)
X   36.920  F   X   36.920  F   X   37.343  F   X   36.809  F   X   36.837  F   X   36.955  F   X   37.003  F
X RHS= 2.684E-04 X RHS= 2.684E-04 X RHS= 2.726E-04 X RHS= 2.684E-04 X RHS= 2.702E-04 X RHS= 2.724E-04 X RHS= 2.733E-04
     10       0.0      1       2.898      1       4.633      1       4.771      1       4.007      1       2.978      1       2.127
X TNU= 9.745E-01 X TNU= 9.745E-01 X TNU= 1.005E+00 X TNU= 7.066E-01 X TNU= 4.912E-01 X TNU= 3.929E-01 X TNU= 3.880E-01
X TKE= 6.361E-02 X TKE= 6.361E-02 X TKE= 6.257E-02 X TKE= 3.913E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02
X CHI= 1.059E-02 X CHI= 1.059E-02 X CHI= 1.176E-02 X CHI= 8.072E-03 X CHI= 4.356E-03 X CHI= 2.072E-03 X CHI= 1.207E-03
X VAP= 2.685E-04 X VAP= 2.685E-04 X VAP= 2.727E-04 X VAP= 2.379E-04 X VAP= 1.994E-04 X VAP= 1.755E-04 X VAP= 1.655E-04
X LIQ= 2.620E-05 X LIQ= 2.620E-05 X LIQ= 8.014E-06 X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   9.763 XXXXXXXXX   9.763 XXXXXXXXX   3.361 XXXXXXXXX  -0.782 XXXXXXXXX  -2.288 XXXXXXXXX  -2.419 XXXXXXXXX  -1.985 XXXX
X       V       X       V       X       V       X      V10      X               X               X
X    ( 1,13)    X    ( 2,13)    X    ( 3,13)    X    ( 4,13)    X    ( 5,13)    X    ( 6,13)    X    ( 7,13)
X   36.296  F   X   36.296  F   X   37.502  F   X   36.782  F   X   36.719  F   X   36.775  F   X   36.844  F
X RHS= 2.695E-04 X RHS= 2.695E-04 X RHS= 2.818E-04 X RHS= 2.749E-04 X RHS= 2.760E-04 X RHS= 2.778E-04 X RHS= 2.791E-04
     10       0.0      1       1.822      1       3.182      1       3.578      1       3.171      1       2.446      1       1.800
X TNU= 7.499E-01 X TNU= 7.499E-01 X TNU= 1.052E+00 X TNU= 7.868E-01 X TNU= 5.579E-01 X TNU= 4.394E-01 X TNU= 4.350E-01
X TKE= 4.102E-02 X TKE= 4.102E-02 X TKE= 6.296E-02 X TKE= 4.057E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02
X CHI= 7.662E-03 X CHI= 7.662E-03 X CHI= 1.259E-02 X CHI= 1.032E-02 X CHI= 6.096E-03 X CHI= 2.902E-03 X CHI= 1.446E-03
X VAP= 2.696E-04 X VAP= 2.696E-04 X VAP= 2.818E-04 X VAP= 2.607E-04 X VAP= 2.188E-04 X VAP= 1.878E-04 X VAP= 1.735E-04
X LIQ= 1.331E-05 X LIQ= 1.331E-05 X LIQ= 1.006E-05 X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  2.0066E+02 , CYCLE NUMBER =   62 ,  PRESSURE ITERATION NUMBER =   4 , DT =  3.1448E+00
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XXXXX  11.535 XXXXXXXXX  11.535 XXXXXXXXX   4.696 XXXXXXXXX  -0.411 XXXXXXXXX  -2.718 XXXXXXXXX  -3.165 XXXXXXXXX  -2.651 XXXX
X        V        X        V        X        V        X       V10       X                 X                 X
X     ( 1,12)     X     ( 2,12)     X     ( 3,12)     X     ( 4,12)     X     ( 5,12)     X     ( 6,12)     X     ( 7,12)
X   35.714  F     X   35.714  F     X   37.121  F     X   36.913  F     X   36.754  F     X   36.698  F     X   36.719  F
X RHS= 2.711E-04  X RHS= 2.711E-04  X RHS= 2.854E-04  X RHS= 2.840E-04  X RHS= 2.840E-04  X RHS= 2.847E-04  X RHS= 2.855E-04
    10       0.0      1       1.101     1       1.585     1       1.953     1       1.847     1       1.535     1       1.220
X TNU= 6.701E-01  X TNU= 6.701E-01  X TNU= 1.082E+00  X TNU= 8.031E-01  X TNU= 5.601E-01  X TNU= 4.770E-01  X TNU= 4.770E-01
X TKE= 3.583E-02  X TKE= 3.583E-02  X TKE= 6.509E-02  X TKE= 3.948E-02  X TKE= 3.030E-02  X TKE= 3.030E-02  X TKE= 3.030E-02
X CHI= 5.326E-03  X CHI= 5.326E-03  X CHI= 1.211E-02  X CHI= 1.084E-02  X CHI= 6.468E-03  X CHI= 3.055E-03  X CHI= 1.496E-03
X VAP= 2.697E-04  X VAP= 2.697E-04  X VAP= 2.855E-04  X VAP= 2.657E-04  X VAP= 2.241E-04  X VAP= 1.927E-04  X VAP= 1.785E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 3.484E-06  X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX  12.606 XXXXXXXXX  12.606 XXXXXXXXX   5.159 XXXXXXXXX  -0.061 XXXXXXXXX  -2.842 XXXXXXXXX  -3.496 XXXXXXXXX  -2.983 XXXX
X       V10       X       V10       X       V10       X       V20       X                 X                 X
X     ( 1,11)     X     ( 2,11)     X     ( 3,11)     X     ( 4,11)     X     ( 5,11)     X     ( 6,11)     X     ( 7,11)
X   36.040  F     X   36.040  F     X   36.560  F     X   36.809  F     X   36.719  F     X   36.671  F     X   36.643  F
X RHS= 2.826E-04  X RHS= 2.826E-04  X RHS= 2.876E-04  X RHS= 2.912E-04  X RHS= 2.918E-04  X RHS= 2.924E-04  X RHS= 2.925E-04
    10       0.0      1       0.258     1      -0.109     1       0.308     1       0.426     1       0.482     1       0.499
X TNU= 6.498E-01  X TNU= 6.498E-01  X TNU= 1.075E+00  X TNU= 7.430E-01  X TNU= 5.169E-01  X TNU= 5.150E-01  X TNU= 5.150E-01
X TKE= 3.610E-02  X TKE= 3.610E-02  X TKE= 6.573E-02  X TKE= 3.330E-02  X TKE= 3.050E-02  X TKE= 3.050E-02  X TKE= 3.050E-02
X CHI= 3.992E-03  X CHI= 3.992E-03  X CHI= 1.097E-02  X CHI= 9.897E-03  X CHI= 5.606E-03  X CHI= 2.561E-03  X CHI= 1.332E-03
X VAP= 2.625E-04  X VAP= 2.625E-04  X VAP= 2.778E-04  X VAP= 2.573E-04  X VAP= 2.189E-04  X VAP= 1.921E-04  X VAP= 1.819E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX  12.861 XXXXXXXXX  12.861 XXXXXXXXX   4.775 XXXXXXXXX   0.340 XXXXXXXXX  -2.736 XXXXXXXXX  -3.453 XXXXXXXXX  -2.979 XXXX
X       V20       X       V20       X       V20       X                 X                 X                 X
X     ( 1,10)     X     ( 2,10)     X     ( 3,10)     X     ( 4,10)     X     ( 5,10)     X     ( 6,10)     X     ( 7,10)
X   36.588  F     X   36.588  F     X   36.359  F     X   36.615  F     X   36.511  F     X   36.456  F     X   36.435  F
X RHS= 2.969E-04  X RHS= 2.969E-04  X RHS= 2.943E-04  X RHS= 2.981E-04  X RHS= 2.981E-04  X RHS= 2.983E-04  X RHS= 2.983E-04
    10       0.0      1      -0.809     1      -1.560     1      -1.192     1      -0.846     1      -0.498     1      -0.232
X TNU= 6.645E-01  X TNU= 6.645E-01  X TNU= 9.770E-01  X TNU= 6.341E-01  X TNU= 5.530E-01  X TNU= 5.530E-01  X TNU= 5.530E-01
X TKE= 3.926E-02  X TKE= 3.926E-02  X TKE= 6.008E-02  X TKE= 3.060E-02  X TKE= 3.060E-02  X TKE= 3.060E-02  X TKE= 3.060E-02
X CHI= 3.422E-03  X CHI= 3.422E-03  X CHI= 8.806E-03  X CHI= 7.435E-03  X CHI= 4.043E-03  X CHI= 1.860E-03  X CHI= 1.137E-03
X VAP= 2.581E-04  X VAP= 2.581E-04  X VAP= 2.596E-04  X VAP= 2.384E-04  X VAP= 2.090E-04  X VAP= 1.904E-04  X VAP= 1.853E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX  12.077 XXXXXXXXX  12.077 XXXXXXXXX   4.015 XXXXXXXXX   0.698 XXXXXXXXX  -2.400 XXXXXXXXX  -3.114 XXXXXXXXX  -2.722 XXXX
X       V20       X       V20       X                 X                 X                 X                 X
X     ( 1, 9)     X     ( 2, 9)     X     ( 3, 9)     X     ( 4, 9)     X     ( 5, 9)     X     ( 6, 9)     X     ( 7, 9)
X   37.246  F     X   37.246  F     X   36.241  F     X   36.449  F     X   36.407  F     X   36.373  F     X   36.393  F
X RHS= 3.131E-04  X RHS= 3.131E-04  X RHS= 3.020E-04  X RHS= 3.054E-04  X RHS= 3.056E-04  X RHS= 3.057E-04  X RHS= 3.060E-04
    10       0.0      1      -1.447     1      -2.294     1      -2.346     1      -1.826     1      -1.290     1      -0.870
X TNU= 6.612E-01  X TNU= 6.612E-01  X TNU= 8.391E-01  X TNU= 5.650E-01  X TNU= 5.650E-01  X TNU= 5.650E-01  X TNU= 5.650E-01
X TKE= 4.114E-02  X TKE= 4.114E-02  X TKE= 5.199E-02  X TKE= 3.090E-02  X TKE= 3.090E-02  X TKE= 3.090E-02  X TKE= 3.090E-02
X CHI= 2.861E-03  X CHI= 2.861E-03  X CHI= 6.057E-03  X CHI= 4.394E-03  X CHI= 2.682E-03  X CHI= 1.399E-03  X CHI= 1.047E-03
X VAP= 2.546E-04  X VAP= 2.546E-04  X VAP= 2.413E-04  X VAP= 2.192E-04  X VAP= 2.023E-04  X VAP= 1.919E-04  X VAP= 1.907E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX  10.678 XXXXXXXXX  10.678 XXXXXXXXX   3.168 XXXXXXXXX   0.646 XXXXXXXXX  -1.881 XXXXXXXXX  -2.578 XXXXXXXXX  -2.304 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1, 8)     X     ( 2, 8)     X     ( 3, 8)     X     ( 4, 8)     X     ( 5, 8)     X     ( 6, 8)     X     ( 7, 8)
X   37.925  F     X   37.925  F     X   36.262  F     X   36.359  F     X   36.373  F     X   36.435  F     X   36.491  F
X RHS= 3.304E-04  X RHS= 3.304E-04  X RHS= 3.112E-04  X RHS= 3.132E-04  X RHS= 3.139E-04  X RHS= 3.148E-04  X RHS= 3.154E-04
    10       0.0      1      -1.616     1      -2.631     1      -2.912     1      -2.383     1      -1.779     1      -1.292
X TNU= 6.196E-01  X TNU= 6.196E-01  X TNU= 7.365E-01  X TNU= 5.400E-01  X TNU= 5.400E-01  X TNU= 5.400E-01  X TNU= 5.400E-01
X TKE= 3.954E-02  X TKE= 3.954E-02  X TKE= 4.590E-02  X TKE= 3.120E-02  X TKE= 3.120E-02  X TKE= 3.120E-02  X TKE= 3.120E-02
X CHI= 2.198E-03  X CHI= 2.198E-03  X CHI= 3.995E-03  X CHI= 2.620E-03  X CHI= 1.772E-03  X CHI= 1.153E-03  X CHI= 1.013E-03
X VAP= 2.532E-04  X VAP= 2.532E-04  X VAP= 2.318E-04  X VAP= 2.131E-04  X VAP= 2.025E-04  X VAP= 1.980E-04  X VAP= 1.996E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
TIME=  2.0066E+02 , CYCLE NUMBER =   62 ,  PRESSURE ITERATION NUMBER =   4 , DT =  3.1448E+00
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XXXXX   9.133 XXXXXXXXX   9.133 XXXXXXXXX   2.160 XXXXXXXXX   0.370 XXXXXXXXX  -1.346 XXXXXXXXX  -1.968 XXXXXXXXX  -1.811 XXXX
X                 X                 X                 X                 X                 X                 X
X    ( 1, 7)      X    ( 2, 7)      X    ( 3, 7)      X    ( 4, 7)      X    ( 5, 7)      X    ( 6, 7)      X    ( 7, 7)
X    38.306  F    X    38.306  F    X    36.484  F    X    36.484  F    X    36.470  F    X    36.456  F    X    36.497  F
X  RHS= 3.443E-04 X  RHS= 3.443E-04 X  RHS= 3.226E-04 X  RHS= 3.232E-04 X  RHS= 3.234E-04 X  RHS= 3.233E-04 X  RHS= 3.236E-04
     10      0.0       1     -1.554      1     -2.565      1     -2.890      1     -2.487      1     -1.900      1     -1.407
X  TNU= 5.589E-01 X  TNU= 5.589E-01 X  TNU= 6.349E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01
X  TKE= 3.609E-02 X  TKE= 3.609E-02 X  TKE= 4.010E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 1.668E-03 X  CHI= 1.668E-03 X  CHI= 2.727E-03 X  CHI= 1.767E-03 X  CHI= 1.298E-03 X  CHI= 1.047E-03 X  CHI= 1.003E-03
X  VAP= 2.544E-04 X  VAP= 2.544E-04 X  VAP= 2.308E-04 X  VAP= 2.176E-04 X  VAP= 2.103E-04 X  VAP= 2.091E-04 X  VAP= 2.120E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   7.664 XXXXXXXXX   7.664 XXXXXXXXX   1.166 XXXXXXXXX   0.057 XXXXXXXXX  -0.932 XXXXXXXXX  -1.372 XXXXXXXXX  -1.310 XXXX
X                 X                 X                 X                 X                 X                 X
X    ( 1, 6)      X    ( 2, 6)      X    ( 3, 6)      X    ( 4, 6)      X    ( 5, 6)      X    ( 6, 6)      X    ( 7, 6)
X    38.396  F    X    38.396  F    X    36.865  F    X    36.733  F    X    36.685  F    X    36.657  F    X    36.664  F
X  RHS= 3.549E-04 X  RHS= 3.549E-04 X  RHS= 3.362E-04 X  RHS= 3.349E-04 X  RHS= 3.345E-04 X  RHS= 3.341E-04 X  RHS= 3.341E-04
     10      0.0       1     -1.368      1     -2.229      1     -2.458      1     -2.217      1     -1.766      1     -1.378
X  TNU= 4.978E-01 X  TNU= 4.978E-01 X  TNU= 5.272E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01
X  TKE= 3.286E-02 X  TKE= 3.286E-02 X  TKE= 3.391E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02
X  CHI= 1.309E-03 X  CHI= 1.309E-03 X  CHI= 1.901E-03 X  CHI= 1.344E-03 X  CHI= 1.099E-03 X  CHI= 1.011E-03 X  CHI= 1.001E-03
X  VAP= 2.573E-04 X  VAP= 2.573E-04 X  VAP= 2.346E-04 X  VAP= 2.272E-04 X  VAP= 2.227E-04 X  VAP= 2.228E-04 X  VAP= 2.253E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   6.376 XXXXXXXXX   6.376 XXXXXXXXX   0.334 XXXXXXXXX  -0.148 XXXXXXXXX  -0.672 XXXXXXXXX  -0.906 XXXXXXXXX  -0.908 XXXX
X                 X                 X                 X                 X                 X                 X
X    ( 1, 5)      X    ( 2, 5)      X    ( 3, 5)      X    ( 4, 5)      X    ( 5, 5)      X    ( 6, 5)      X    ( 7, 5)
X    38.279  F    X    38.279  F    X    36.712  F    X    36.719  F    X    36.705  F    X    36.712  F    X    36.691  F
X  RHS= 3.628E-04 X  RHS= 3.628E-04 X  RHS= 3.431E-04 X  RHS= 3.434E-04 X  RHS= 3.433E-04 X  RHS= 3.434E-04 X  RHS= 3.431E-04
     10      0.0       1     -1.243      1     -1.732      1     -2.019      1     -1.918      1     -1.641      1     -1.354
X  TNU= 4.523E-01 X  TNU= 4.523E-01 X  TNU= 4.132E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01
X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02
X  CHI= 1.108E-03 X  CHI= 1.108E-03 X  CHI= 1.329E-03 X  CHI= 1.107E-03 X  CHI= 1.025E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03
X  VAP= 2.612E-04 X  VAP= 2.612E-04 X  VAP= 2.414E-04 X  VAP= 2.376E-04 X  VAP= 2.354E-04 X  VAP= 2.358E-04 X  VAP= 2.372E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   5.204 XXXXXXXXX   5.204 XXXXXXXXX  -0.128 XXXXXXXXX  -0.411 XXXXXXXXX  -0.549 XXXXXXXXX  -0.608 XXXXXXXXX  -0.601 XXXX
X                 X                 X                 X                 X                 X                 X
X    ( 1, 4)      X    ( 2, 4)      X    ( 3, 4)      X    ( 4, 4)      X    ( 5, 4)      X    ( 6, 4)      X    ( 7, 4)
X    38.223  F    X    38.223  F    X    36.754  F    X    36.594  F    X    36.553  F    X    36.567  F    X    36.594  F
X  RHS= 3.717E-04 X  RHS= 3.717E-04 X  RHS= 3.526E-04 X  RHS= 3.506E-04 X  RHS= 3.501E-04 X  RHS= 3.502E-04 X  RHS= 3.506E-04
     10      0.0       1     -1.394      1     -1.360      1     -1.478      1     -1.407      1     -1.208      1     -1.013
X  TNU= 4.384E-01 X  TNU= 4.384E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01
X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02
X  CHI= 1.029E-03 X  CHI= 1.029E-03 X  CHI= 1.078E-03 X  CHI= 1.031E-03 X  CHI= 1.005E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03
X  VAP= 2.654E-04 X  VAP= 2.654E-04 X  VAP= 2.509E-04 X  VAP= 2.483E-04 X  VAP= 2.476E-04 X  VAP= 2.482E-04 X  VAP= 2.491E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   3.863 XXXXXXXXX   3.863 XXXXXXXXX  -0.066 XXXXXXXXX  -0.502 XXXXXXXXX  -0.455 XXXXXXXXX  -0.388 XXXXXXXXX  -0.387 XXXX
X                 X                 X                 X                 X                 X                 X
X    ( 1, 3)      X    ( 2, 3)      X    ( 3, 3)      X    ( 4, 3)      X    ( 5, 3)      X    ( 6, 3)      X    ( 7, 3)
X    38.251  F    X    38.251  F    X    37.454  F    X    37.225  F    X    37.121  F    X    37.003  F    X    36.879  F
X  RHS= 3.820E-04 X  RHS= 3.820E-04 X  RHS= 3.712E-04 X  RHS= 3.682E-04 X  RHS= 3.668E-04 X  RHS= 3.651E-04 X  RHS= 3.634E-04
     10      0.0       1     -1.660      1     -1.531      1     -1.312      1     -1.143      1     -1.011      1     -0.906
X  TNU= 4.426E-01 X  TNU= 4.426E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02
X  CHI= 1.008E-03 X  CHI= 1.008E-03 X  CHI= 1.011E-03 X  CHI= 1.008E-03 X  CHI= 1.002E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03
X  VAP= 2.700E-04 X  VAP= 2.700E-04 X  VAP= 2.621E-04 X  VAP= 2.599E-04 X  VAP= 2.601E-04 X  VAP= 2.607E-04 X  VAP= 2.612E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  2.0066E+02 , CYCLE NUMBER =    62 ,  PRESSURE ITERATION NUMBER =    4 , DT =  3.1448E+00
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XXXXX   2.240 XXXXXXXXX   2.240 XXXXXXXXX   0.086 XXXXXXXXX  -0.260 XXXXXXXXX  -0.265 XXXXXXXXX  -0.235 XXXXXXXXX  -0.261 XXXX
X                X                X                X                X                X                X
X     ( 1, 2)    X     ( 2, 2)    X     ( 3, 2)    X     ( 4, 2)    X     ( 5, 2)    X     ( 6, 2)    X     ( 7, 2)
X    38.265  F   X    38.265  F   X    37.856  F   X    37.731  F   X    37.641  F   X    37.537  F   X    37.412  F
X  RHS= 3.923E-04 X  RHS= 3.923E-04 X  RHS= 3.864E-04 X  RHS= 3.847E-04 X  RHS= 3.834E-04 X  RHS= 3.819E-04 X  RHS= 3.801E-04
      10       0.0       1      -2.265       1      -2.379       1      -2.152       1      -1.925       1      -1.730       1      -1.510
X  TNU= 4.742E-01 X  TNU= 4.742E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.004E-03 X  CHI= 1.004E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03
X  VAP= 2.748E-04 X  VAP= 2.748E-04 X  VAP= 2.738E-04 X  VAP= 2.729E-04 X  VAP= 2.729E-04 X  VAP= 2.731E-04 X  VAP= 2.732E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                X                X                X                X                X                X
X     ( 1, 1)    X     ( 2, 1)    X     ( 3, 1)    X     ( 4, 1)    X     ( 5, 1)    X     ( 6, 1)    X     ( 7, 1)
X    38.265  F   X    38.265  F   X    37.856  F   X    37.731  F   X    37.641  F   X    37.537  F   X    37.412  F
X  RHS= 3.923E-04 X  RHS= 3.923E-04 X  RHS= 3.864E-04 X  RHS= 3.847E-04 X  RHS= 3.834E-04 X  RHS= 3.819E-04 X  RHS= 3.801E-04
       2       2.265      10       2.265      10       2.379      10       2.152      10       1.925      10       1.730      10       1.510
X  TNU= 4.742E-01 X  TNU= 4.742E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.004E-03 X  CHI= 1.004E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03
X  VAP= 2.748E-04 X  VAP= 2.748E-04 X  VAP= 2.738E-04 X  VAP= 2.729E-04 X  VAP= 2.729E-04 X  VAP= 2.731E-04 X  VAP= 2.732E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  2.0066E+02 , CYCLE NUMBER =   62 ,  PRESSURE ITERATION NUMBER =   4 , DT =  3.1448E+00
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PLUME CENTER AT 1678.56 FEET. PLUME SPEED IS   16.06  DOWNWIND DISTANCE IS 2903.
   TOTAL  ENERGY   ON MESH IS   0.73843E+09
TIME=  2.0066E+02 , CYCLE NUMBER =    62 ,  PRESSURE ITERATION NUMBER =    4 , DT =  3.1448E+00 , MAX DIVERGENCE =  5.1403E-04
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XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X     ( 1,22)    X     ( 2,22)    X     ( 3,22)    X     ( 4,22)    X     ( 5,22)    X     ( 6,22)    X     ( 7,22)
X    41.148  F   X    41.148  F   X    40.926  F   X    41.058  F   X    41.120  F   X    41.162  F   X    41.162  F
X  RHS= 3.722E-04 X  RHS= 3.716E-04 X  RHS= 3.714E-04 X  RHS= 3.714E-04 X  RHS= 3.714E-04 X  RHS= 3.718E-04 X  RHS= 3.625E-04
       2      0.0       10      -1.173      10      -0.680      10      -0.455      10      -0.436      10      -0.562      10      -0.621
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0
X  VAP= 1.087E-04 X  VAP= 1.087E-04 X  VAP= 1.103E-04 X  VAP= 1.089E-04 X  VAP= 1.081E-04 X  VAP= 1.075E-04 X  VAP= 1.076E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                X                X                X                X                X
X     ( 1,21)    X     ( 2,21)    X     ( 3,21)    X     ( 4,21)    X     ( 5,21)    X     ( 6,21)    X     ( 7,21)
X    41.148  F   X    41.148  F   X    40.926  F   X    41.058  F   X    41.120  F   X    41.162  F   X    41.162  F
X  RHS= 2.644E-04 X  RHS= 2.644E-04 X  RHS= 2.621E-04 X  RHS= 2.634E-04 X  RHS= 2.641E-04 X  RHS= 2.646E-04 X  RHS= 2.645E-04
      10      0.0        1      -1.173       1      -0.680       1      -0.455       1      -0.436       1      -0.562       1      -0.621
X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 9.987E-04 X  CHI= 9.987E-04 X  CHI= 9.985E-04 X  CHI= 9.985E-04 X  CHI= 9.985E-04 X  CHI= 9.985E-04 X  CHI= 9.986E-04
X  VAP= 1.087E-04 X  VAP= 1.087E-04 X  VAP= 1.103E-04 X  VAP= 1.089E-04 X  VAP= 1.081E-04 X  VAP= 1.075E-04 X  VAP= 1.076E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -1.257 XXXXXXXXX  -1.257 XXXXXXXXX   0.469 XXXXXXXXX   0.203 XXXXXXXXX  -0.001 XXXXXXXXX  -0.146 XXXXXXXXX  -0.078 XXXX
X                X                X                X                X                X                X
X     ( 1,20)    X     ( 2,20)    X     ( 3,20)    X     ( 4,20)    X     ( 5,20)    X     ( 6,20)    X     ( 7,20)
X    40.531  F   X    40.531  F   X    40.198  F   X    40.358  F   X    40.399  F   X    40.420  F   X    40.441  F
X  RHS= 2.657E-04 X  RHS= 2.657E-04 X  RHS= 2.620E-04 X  RHS= 2.637E-04 X  RHS= 2.641E-04 X  RHS= 2.644E-04 X  RHS= 2.646E-04
      10      0.0        1       0.539       1       0.533       1       0.358       1       0.122       1      -0.049       1      -0.275
X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02 X  TNU= 3.200E-02
X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02
X  CHI= 9.976E-04 X  CHI= 9.976E-04 X  CHI= 9.993E-04 X  CHI= 9.985E-04 X  CHI= 9.985E-04 X  CHI= 9.985E-04 X  CHI= 9.985E-04
X  VAP= 1.094E-04 X  VAP= 1.094E-04 X  VAP= 1.179E-04 X  VAP= 1.166E-04 X  VAP= 1.158E-04 X  VAP= 1.152E-04 X  VAP= 1.149E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -0.802 XXXXXXXXX  -0.802 XXXXXXXXX   0.439 XXXXXXXXX   0.006 XXXXXXXXX  -0.258 XXXXXXXXX  -0.337 XXXXXXXXX  -0.323 XXXX
X                X                X                X                X                X                X
X     ( 1,19)    X     ( 2,19)    X     ( 3,19)    X     ( 4,19)    X     ( 5,19)    X     ( 6,19)    X     ( 7,19)
X    40.136  F   X    40.136  F   X    39.644  F   X    39.498  F   X    39.575  F   X    39.637  F   X    39.672  F
X  RHS= 2.691E-04 X  RHS= 2.691E-04 X  RHS= 2.638E-04 X  RHS= 2.622E-04 X  RHS= 2.630E-04 X  RHS= 2.63[illegible]E-04 X  RHS= 2.641E-04
      10      0.0        1       1.864       1       1.736       1       1.347       1       0.877       1       0.521       1       0.287
X  TNU= 2.606E-02 X  TNU= 2.606E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.470E-02 X  TNU= 2.4[illegible]0E-02 X  TNU= 2.470E-02
X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02
X  CHI= 1.069E-03 X  CHI= 1.069E-03 X  CHI= 1.020E-03 X  CHI= 1.000E-03 X  CHI= 9.983E-04 X  CHI= 9.983E-04 X  CHI= 9.983E-04
X  VAP= 1.147E-04 X  VAP= 1.147E-04 X  VAP= 1.225E-04 X  VAP= 1.249E-04 X  VAP= 1.244E-04 X  VAP= 1.238E-04 X  VAP= 1.231E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.989 XXXXXXXXX   0.989 XXXXXXXXX   0.284 XXXXXXXXX  -0.410 XXXXXXXXX  -0.753 XXXXXXXXX  -0.717 XXXXXXXXX  -0.579 XXXX
X                X                X                X                X                X                X
X     ( 1,18)    X     ( 2,18)    X     ( 3,18)    X     ( 4,18)    X     ( 5,18)    X     ( 6,18)    X     ( 7,18)
X    39.124  F   X    39.124  F   X    39.492  F   X    39.311  F   X    39.374  F   X    39.471  F   X    39.533  F
X  RHS= 2.644E-04 X  RHS= 2.644E-04 X  RHS= 2.693E-04 X  RHS= 2.677E-04 X  RHS= 2.683E-04 X  RHS= 2.694E-04 X  RHS= 2.700E-04
      10      0.0        1       3.145       1       3.353       1       2.700       1       1.919       1       1.239       1       0.807
X  TNU= 5.349E-01 X  TNU= 5.349E-01 X  TNU= 1.536E-01 X  TNU= 5.448E-02 X  TNU= 5.300E-02 X  TNU= 5.300E-02 X  TNU= 5.3[illegible]E-02
X  TKE= 4.425E-02 X  TKE= 4.425E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02 X  TKE= 2.400E-02
X  CHI= 2.705E-03 X  CHI= 2.705E-03 X  CHI= 1.598E-03 X  CHI= 1.120E-03 X  CHI= 1.014E-03 X  CHI= 1.000E-03 X  CHI= 9.993E-04
X  VAP= 1.684E-04 X  VAP= 1.684E-04 X  VAP= 1.395E-04 X  VAP= 1.332E-04 X  VAP= 1.326E-04 X  VAP= 1.320E-04 X  VAP= 1.312E-04
X  LIQ= [illegible]  X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.[illegible]  X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME= 3[illegible]9E+02 , CYCLE NUMBER =   95 ,  PRESSURE ITERATION NUM[illegible]R =   2 , DT =  3.0408E+00
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XXXXX    4.070 XXXXXXXXX    4.070 XXXXXXXXX    0.475 XXXXXXXXX   -1.080 XXXXXXXXX   -1.550 XXXXXXXXX   -1.413 XXXXXXXXX   -1.027 XXXX
X         V10     X         V10     X                 X                 X                 X                 X
X     ( 1,17)     X     ( 2,17)     X     ( 3,17)     X     ( 4,17)     X     ( 5,17)     X     ( 6,17)     X     ( 7,17)
X    37.904   F   X    37.904   F   X    38.688   F   X    38.438   F   X    38.403   F   X    38.459   F   X    38.500   F
X  RHS= 2.569E-04 X  RHS= 2.569E-04 X  RHS= 2.661E-04 X  RHS= 2.652E-04 X  RHS= 2.656E-04 X  RHS= 2.664E-04 X  RHS= 2.668E-04
      10       0.0       1      3.553       1      4.734       1      4.287       1      3.191       1      2.057       1      1.280
X  TNU= 1.326E+00 X  TNU= 1.326E+00 X  TNU= 8.783E-01 X  TNU= 4.114E-01 X  TNU= 2.034E-01 X  TNU= 1.800E-01 X  TNU= 1.800E-01
X  TKE= 9.947E-02 X  TKE= 9.947E-02 X  TKE= 5.935E-02 X  TKE= 3.007E-02 X  TKE= 2.550E-02 X  TKE= 2.550E-02 X  TKE= 2.550E-02
X  CHI= 4.484E-03 X  CHI= 4.484E-03 X  CHI= 4.128E-03 X  CHI= 2.507E-03 X  CHI= 1.488E-03 X  CHI= 1.097E-03 X  CHI= 1.010E-03
X  VAP= 2.427E-04 X  VAP= 2.427E-04 X  VAP= 2.059E-04 X  VAP= 1.648E-04 X  VAP= 1.454E-04 X  VAP= 1.396E-04 X  VAP= 1.384E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    7.549 XXXXXXXXX    7.549 XXXXXXXXX    1.643 XXXXXXXXX   -1.541 XXXXXXXXX   -2.663 XXXXXXXXX   -2.563 XXXXXXXXX   -1.820 XXXX
X         V       X         V       X         V10     X         V20     X                 X                 X
X     ( 1,16)     X     ( 2,16)     X     ( 3,16)     X     ( 4,16)     X     ( 5,16)     X     ( 6,16)     X     ( 7,16)
X    36.934   F   X    36.934   F   X    38.251   F   X    38.036   F   X    37.918   F   X    37.925   F   X    38.001   F
X  RHS= 2.543E-04 X  RHS= 2.543E-04 X  RHS= 2.674E-04 X  RHS= 2.666E-04 X  RHS= 2.668E-04 X  RHS= 2.678E-04 X  RHS= 2.690E-04
      10       0.0       1      2.916       1      4.554       1      4.786       1      4.148       1      3.094       1      2.044
X  TNU= 1.197E+00 X  TNU= 1.197E+00 X  TNU= 1.337E+00 X  TNU= 9.037E-01 X  TNU= 5.346E-01 X  TNU= 3.198E-01 X  TNU= 2.560E-01
X  TKE= 7.943E-02 X  TKE= 7.943E-02 X  TKE= 8.662E-02 X  TKE= 5.363E-02 X  TKE= 3.287E-02 X  TKE= 2.700E-02 X  TKE= 2.700E-02
X  CHI= 3.825E-03 X  CHI= 3.825E-03 X  CHI= 5.997E-03 X  CHI= 5.117E-03 X  CHI= 3.485E-03 X  CHI= 2.155E-03 X  CHI= 1.373E-03
X  VAP= 2.544E-04 X  VAP= 2.544E-04 X  VAP= 2.571E-04 X  VAP= 2.210E-04 X  VAP= 1.844E-04 X  VAP= 1.609E-04 X  VAP= 1.493E-04
X  LIQ= 1.137E-06 X  LIQ= 1.137E-06 X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   10.388 XXXXXXXXX   10.388 XXXXXXXXX    3.264 XXXXXXXXX   -1.327 XXXXXXXXX   -3.317 XXXXXXXXX   -3.632 XXXXXXXXX   -2.886 XXXX
X         V10     X         V10     X         V10     X         V10     X         V20     X                 X
X     ( 1,15)     X     ( 2,15)     X     ( 3,15)     X     ( 4,15)     X     ( 5,15)     X     ( 6,15)     X     ( 7,15)
X    36.179   F   X    36.179   F   X    37.648   F   X    37.738   F   X    37.669   F   X    37.662   F   X    37.717   F
X  RHS= 2.541E-04 X  RHS= 2.541E-04 X  RHS= 2.684E-04 X  RHS= 2.698E-04 X  RHS= 2.704E-04 X  RHS= 2.715E-04 X  RHS= 2.728E-04
      10       0.0       1      1.988       1      3.214       1      3.850       1      3.806       1      3.324       1      2.678
X  TNU= 9.786E-01 X  TNU= 9.786E-01 X  TNU= 1.367E+00 X  TNU= 1.092E+00 X  TNU= 7.398E-01 X  TNU= 4.828E-01 X  TNU= 3.433E-01
X  TKE= 5.647E-02 X  TKE= 5.647E-02 X  TKE= 8.378E-02 X  TKE= 5.894E-02 X  TKE= 3.777E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02
X  CHI= 3.214E-03 X  CHI= 3.214E-03 X  CHI= 6.559E-03 X  CHI= 6.891E-03 X  CHI= 5.477E-03 X  CHI= 3.792E-03 X  CHI= 2.473E-03
X  VAP= 2.506E-04 X  VAP= 2.506E-04 X  VAP= 2.649E-04 X  VAP= 2.520E-04 X  VAP= 2.182E-04 X  VAP= 1.882E-04 X  VAP= 1.692E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   12.319 XXXXXXXXX   12.319 XXXXXXXXX    4.461 XXXXXXXXX   -0.711 XXXXXXXXX   -3.378 XXXXXXXXX   -4.128 XXXXXXXXX   -3.546 XXXX
X         V10     X         V10     X         V10     X         V10     X         V20     X                 X
X     ( 1,14)     X     ( 2,14)     X     ( 3,14)     X     ( 4,14)     X     ( 5,14)     X     ( 6,14)     X     ( 7,14)
X    36.005   F   X    36.005   F   X    36.990   F   X    37.267   F   X    37.378   F   X    37.405   F   X    37.454   F
X  RHS= 2.599E-04 X  RHS= 2.599E-04 X  RHS= 2.694E-04 X  RHS= 2.721E-04 X  RHS= 2.744E-04 X  RHS= 2.758E-04 X  RHS= 2.773E-04
      10       0.0       1      0.899       1      1.361       1      2.185       1      2.559       1      2.581       1      2.381
X  TNU= 8.874E-01 X  TNU= 8.874E-01 X  TNU= 1.387E+00 X  TNU= 1.112E+00 X  TNU= 8.006E-01 X  TNU= 5.576E-01 X  TNU= 4.019E-01
X  TKE= 4.852E-02 X  TKE= 4.852E-02 X  TKE= 8.265E-02 X  TKE= 5.472E-02 X  TKE= 3.613E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02
X  CHI= 3.019E-03 X  CHI= 3.019E-03 X  CHI= 7.257E-03 X  CHI= 8.393E-03 X  CHI= 7.053E-03 X  CHI= 5.146E-03 X  CHI= 3.434E-03
X  VAP= 2.475E-04 X  VAP= 2.475E-04 X  VAP= 2.622E-04 X  VAP= 2.651E-04 X  VAP= 2.378E-04 X  VAP= 2.075E-04 X  VAP= 1.847E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   13.194 XXXXXXXXX   13.194 XXXXXXXXX    4.892 XXXXXXXXX    0.069 XXXXXXXXX   -3.023 XXXXXXXXX   -4.121 XXXXXXXXX   -3.760 XXXX
X         V10     X         V10     X         V10     X         V10     X         V20     X                 X
X     ( 1,13)     X     ( 2,13)     X     ( 3,13)     X     ( 4,13)     X     ( 5,13)     X     ( 6,13)     X     ( 7,13)
X    36.352   F   X    36.352   F   X    36.456   F   X    36.906   F   X    37.121   F   X    37.204   F   X    37.246   F
X  RHS= 2.710E-04 X  RHS= 2.710E-04 X  RHS= 2.717E-04 X  RHS= 2.759E-04 X  RHS= 2.792E-04 X  RHS= 2.813E-04 X  RHS= 2.827E-04
      10       0.0       1     -0.280       1     -0.516       1      0.459       1      1.007       1      1.347       1      1.491
X  TNU= 8.706E-01 X  TNU= 8.706E-01 X  TNU= 1.400E+00 X  TNU= 1.010E+00 X  TNU= 7.554E-01 X  TNU= 5.440E-01 X  TNU= 4.350E-01
X  TKE= 4.820E-02 X  TKE= 4.820E-02 X  TKE= 8.333E-02 X  TKE= 4.345E-02 X  TKE= 3.020E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02
X  CHI= 3.012E-03 X  CHI= 3.012E-03 X  CHI= 7.911E-03 X  CHI= 1.001E-02 X  CHI= 8.057E-03 X  CHI= 5.783E-03 X  CHI= 3.731E-03
X  VAP= 2.458E-04 X  VAP= 2.458E-04 X  VAP= 2.567E-04 X  VAP= 2.690E-04 X  VAP= 2.448E-04 X  VAP= 2.151E-04 X  VAP= 1.908E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  3.0019E+02 , CYCLE NUMBER =    95 ,  PRESSURE ITERATION NUMBER =   2 , DT =  3.0408E+00
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XXXXX  12.936 XXXXXXXXX  12.936 XXXXXXXXX   4.636 XXXXXXXXX   1.043 XXXXXXXXX  -2.493 XXXXXXXXX  -3.795 XXXXXXXXX  -3.628 XXXX
X         V20    X         V20    X         V20    X         V10    X         V20    X                X
X     ( 1,12)    X     ( 2,12)    X     ( 3,12)    X     ( 4,12)    X     ( 5,12)    X     ( 6,12)    X     ( 7,12)
X    37.003  F   X    37.003  F   X    36.227  F   X    36.726  F   X    36.934  F   X    37.052  F   X    37.128  F
X  RHS= 2.858E-04 X  RHS= 2.858E-04 X  RHS= 2.774E-04 X  RHS= 2.824E-04 X  RHS= 2.852E-04 X  RHS= 2.877E-04 X  RHS= 2.895E-04
     10       0.0       1      -1.111      1      -1.479      1      -1.020      1      -0.360      1       0.145      1       0.521
X  TNU= 8.675E-01 X  TNU= 8.675E-01 X  TNU= 1.246E+00 X  TNU= 8.210E-01 X  TNU= 6.424E-01 X  TNU= 4.799E-01 X  TNU= 4.770E-01
X  TKE= 4.957E-02 X  TKE= 4.957E-02 X  TKE= 7.311E-02 X  TKE= 3.309E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02
X  CHI= 3.014E-03 X  CHI= 3.014E-03 X  CHI= 7.536E-03 X  CHI= 9.481E-03 X  CHI= 7.995E-03 X  CHI= 5.412E-03 X  CHI= 3.218E-03
X  VAP= 2.443E-04 X  VAP= 2.443E-04 X  VAP= 2.468E-04 X  VAP= 2.558E-04 X  VAP= 2.407E-04 X  VAP= 2.116E-04 X  VAP= 1.883E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  11.891 XXXXXXXXX  11.891 XXXXXXXXX   4.262 XXXXXXXXX   1.494 XXXXXXXXX  -1.843 XXXXXXXXX  -3.298 XXXXXXXXX  -3.259 XXXX
X         V20    X         V20    X         V20    X         V20    X                X                X
X     ( 1,11)    X     ( 2,11)    X     ( 3,11)    X     ( 4,11)    X     ( 5,11)    X     ( 6,11)    X     ( 7,11)
X    37.558  F   X    37.558  F   X    36.463  F   X    36.588  F   X    36.858  F   X    36.948  F   X    37.038  F
X  RHS= 3.002E-04 X  RHS= 3.002E-04 X  RHS= 2.884E-04 X  RHS= 2.898E-04 X  RHS= 2.931E-04 X  RHS= 2.950E-04 X  RHS= 2.968E-04
     10       0.0       1      -1.348      1      -1.764      1      -1.946      1      -1.407      1      -0.783      1      -0.268
X  TNU= 8.057E-01 X  TNU= 8.057E-01 X  TNU- 1.023E+00 X  TNU= 6.200E-01 X  TNU= 5.312E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01
X  TKE= 4.647E-02 X  TKE= 4.647E-02 X  TKE= 5.958E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02
X  CHI= 2.624E-03 X  CHI= 2.624E-03 X  CHI= 5.875E-03 X  CHI= 6.978E-03 X  CHI= 6.550E-03 X  CHI= 4.361E-03 X  CHI= 2.428E-03
X  VAP= 2.423E-04 X  VAP= 2.423E-04 X  VAP= 2.324E-04 X  VAP= 2.324E-04 X  VAP= 2.258E-04 X  VAP= 2.031E-04 X  VAP= 1.843E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  10.624 XXXXXXXXX  10.624 XXXXXXXXX   3.856 XXXXXXXXX   1.317 XXXXXXXXX  -1.297 XXXXXXXXX  -2.672 XXXXXXXXX  -2.743 XXXX
X                X                X                X                X                X                X
X     ( 1,10)    X     ( 2,10)    X     ( 3,10)    X     ( 4,10)    X     ( 5,10)    X     ( 6,10)    X     ( 7,10)
X    37.960  F   X    37.960  F   X    36.615  F   X    36.615  F   X    36.782  F   X    36.886  F   X    36.934  F
X  RHS= 3.135E-04 X  RHS= 3.135E-04 X  RHS= 2.988E-04 X  RHS= 2.991E-04 X  RHS= 3.012E-04 X  RHS= 3.031E-04 X  RHS= 3.041E-04
     10       0.0       1      -1.392      1      -1.958      1      -2.254      1      -1.958      1      -1.383      1      -0.860
X  TNU= 7.220E-01 X  TNU= 7.220E-01 X  TNU= 8.585E-01 X  TNU= 5.561E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01
X  TKE= 4.145E-02 X  TKE= 4.145E-02 X  TKE= 4.926E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02
X  CHI= 2.129E-03 X  CHI= 2.129E-03 X  CHI= 4.129E-03 X  CHI= 4.562E-03 X  CHI= 4.505E-03 X  CHI= 3.047E-03 X  CHI= 1.721E-03
X  VAP= 2.416E-04 X  VAP= 2.416E-04 X  VAP= 2.206E-04 X  VAP= 2.138E-04 X  VAP= 2.090E-04 X  VAP= 1.943E-04 X  VAP= 1.827E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   9.323 XXXXXXXXX   9.323 XXXXXXXXX   3.314 XXXXXXXXX   1.037 XXXXXXXXX  -0.993 XXXXXXXXX  -2.089 XXXXXXXXX  -2.213 XXXX
X                X                X                X                X                X                X
X     ( 1, 9)    X     ( 2, 9)    X     ( 3, 9)    X     ( 4, 9)    X     ( 5, 9)    X     ( 6, 9)    X     ( 7, 9)
X    38.078  F   X    38.078  F   X    36.948  F   X    36.768  F   X    36.712  F   X    36.747  F   X    36.740  F
X  RHS= 3.237E-04 X  RHS= 3.237E-04 X  RHS= 3.114E-04 X  RHS= 3.098E-04 X  RHS= 3.094E-04 X  RHS= 3.101E-04 X  RHS= 3.103E-04
     10       0.0       1      -1.373      1      -2.055      1      -2.343      1      -2.174      1      -1.723      1      -1.262
X  TNU= 6.403E-01 X  TNU= 6.403E-01 X  TNU= 7.616E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01
X  TKE= 3.673E-02 X  TKE= 3.673E-02 X  TKE= 4.257E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02
X  CHI= 1.725E-03 X  CHI= 1.725E-03 X  CHI= 2.851E-03 X  CHI= 2.844E-03 X  CHI= 2.804E-03 X  CHI= 2.004E-03 X  CHI= 1.290E-03
X  VAP= 2.428E-04 X  VAP= 2.428E-04 X  VAP= 2.148E-04 X  VAP= 2.039E-04 X  VAP= 1.985E-04 X  VAP= 1.904E-04 X  VAP= 1.854E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   8.036 XXXXXXXXX   8.036 XXXXXXXXX   2.661 XXXXXXXXX   0.771 XXXXXXXXX  -0.807 XXXXXXXXX  -1.627 XXXXXXXXX  -1.741 XXXX
X                X                X                X                X                X                X
X     ( 1, 8)    X     ( 2, 8)    X     ( 3, 8)    X     ( 4, 8)    X     ( 5, 8)    X     ( 6, 8)    X     ( 7, 8)
X    37.932  F   X    37.932  F   X    37.031  F   X    36.920  F   X    36.823  F   X    36.789  F   X    36.754  F
X  RHS= 3.308E-04 X  RHS= 3.308E-04 X  RHS= 3.212E-04 X  RHS= 3.204E-04 X  RHS= 3.195E-04 X  RHS= 3.193E-04 X  RHS= 3.189E-04
     10       0.0       1      -1.263      1      -2.025      1      -2.331      1      -2.204      1      -1.864      1      -1.472
X  TNU= 5.599E-01 X  TNU= 5.599E-01 X  TNU= 6.746E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01
X  TKE= 3.292E-02 X  TKE= 3.292E-02 X  TKE= 3.748E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02
X  CHI= 1.440E-03 X  CHI= 1.440E-03 X  CHI= 2.071E-03 X  CHI= 1.856E-03 X  CHI= 1.771E-03 X  CHI= 1.400E-03 X  CHI= 1.093E-03
X  VAP= 2.460E-04 X  VAP= 2.460E-04 X  VAP= 2.151E-04 X  VAP= 2.030E-04 X  VAP= 1.971E-04 X  VAP= 1.932E-04 X  VAP= 1.926E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  3.0019E+02 , CYCLE NUMBER =    95 ,  PRESSURE ITERATION NUMBER =   2 , DT =  3.0408E+00
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XXXXX   6.842 XXXXXXXXX   6.842 XXXXXXXXX   1.931 XXXXXXXXX   0.492 XXXXXXXXX  -0.656 XXXXXXXXX  -1.268 XXXXXXXXX  -1.334 XXXX
X                   X                   X                   X                   X                   X                   X
X     ( 1, 7)       X     ( 2, 7)       X     ( 3, 7)       X     ( 4, 7)       X     ( 5, 7)       X     ( 6, 7)       X     ( 7, 7)
X    37.856  F      X    37.856  F      X    37.038  F      X    36.913  F      X    36.837  F      X    36.823  F      X    36.816  F
X  RHS= 3.387E-04 X  RHS= 3.387E-04 X  RHS= 3.299E-04 X  RHS= 3.288E-04 X  RHS= 3.281E-04 X  RHS= 3.281E-04 X  RHS= 3.279E-04
       10        0.0       1       -1.102       1      -1.842       1      -2.137       1      -2.053       1      -1.777       1      -1.445
X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 5.776E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01
X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.292E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 1.252E-03 X  CHI= 1.252E-03 X  CHI= 1.631E-03 X  CHI= 1.373E-03 X  CHI= 1.280E-03 X  CHI= 1.131E-03 X  CHI= 1.024E-03
X  VAP= 2.505E-04 X  VAP= 2.505E-04 X  VAP= 2.205E-04 X  VAP= 2.098E-04 X  VAP= 2.043E-04 X  VAP= 2.025E-04 X  VAP= 2.043E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   5.799 XXXXXXXXX   5.799 XXXXXXXXX   1.214 XXXXXXXXX   0.222 XXXXXXXXX  -0.549 XXXXXXXXX  -0.967 XXXXXXXXX  -0.981 XXXX
X                   X                   X                   X                   X                   X                   X
X     ( 1, 6)       X     ( 2, 6)       X     ( 3, 6)       X     ( 4, 6)       X     ( 5, 6)       X     ( 6, 6)       X     ( 7, 6)
X    37.731  F      X    37.731  F      X    37.107  F      X    36.976  F      X    36.886  F      X    36.830  F      X    36.858  F
X  RHS= 3.463E-04 X  RHS= 3.463E-04 X  RHS= 3.395E-04 X  RHS= 3.382E-04 X  RHS= 3.373E-04 X  RHS= 3.366E-04 X  RHS= 3.369E-04
       10        0.0       1       -0.915       1      -1.616       1      -1.840       1      -1.752       1      -1.499       1      -1.242
X  TNU= 4.283E-01 X  TNU= 4.283E-01 X  TNU= 4.723E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01
X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02
X  CHI= 1.129E-03 X  CHI= 1.129E-03 X  CHI= 1.368E-03 X  CHI= 1.159E-03 X  CHI= 1.091E-03 X  CHI= 1.035E-03 X  CHI= 1.005E-03
X  VAP= 2.554E-04 X  VAP= 2.554E-04 X  VAP= 2.289E-04 X  VAP= 2.216E-04 X  VAP= 2.171E-04 X  VAP= 2.161E-04 X  VAP= 2.186E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   4.937 XXXXXXXXX   4.937 XXXXXXXXX   0.534 XXXXXXXXX   0.017 XXXXXXXXX  -0.442 XXXXXXXXX  -0.695 XXXXXXXXX  -0.705 XXXX
X                   X                   X                   X                   X                   X                   X
X     ( 1, 5)       X     ( 2, 5)       X     ( 3, 5)       X     ( 4, 5)       X     ( 5, 5)       X     ( 6, 5)       X     ( 7, 5)
X    37.620  F      X    37.620  F      X    36.906  F      X    36.962  F      X    36.927  F      X    36.872  F      X    36.830  F
X  RHS= 3.541E-04 X  RHS= 3.541E-04 X  RHS= 3.458E-04 X  RHS= 3.467E-04 X  RHS= 3.464E-04 X  RHS= 3.457E-04 X  RHS= 3.451E-04
       10        0.0       1       -0.824       1      -1.306       1      -1.545       1      -1.472       1      -1.272       1      -1.066
X  TNU= 4.019E-01 X  TNU= 4.019E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01
X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02
X  CHI= 1.056E-03 X  CHI= 1.056E-03 X  CHI= 1.168E-03 X  CHI= 1.054E-03 X  CHI= 1.025E-03 X  CHI= 1.007E-03 X  CHI= 1.001E-03
X  VAP= 2.600E-04 X  VAP= 2.600E-04 X  VAP= 2.383E-04 X  VAP= 2.345E-04 X  VAP= 2.313E-04 X  VAP= 2.309E-04 X  VAP= 2.326E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   4.150 XXXXXXXXX   4.150 XXXXXXXXX   0.076 XXXXXXXXX  -0.198 XXXXXXXXX  -0.349 XXXXXXXXX  -0.478 XXXXXXXXX  -0.481 XXXX
X                   X                   X                   X                   X                   X                   X
X     ( 1, 4)       X     ( 2, 4)       X     ( 3, 4)       X     ( 4, 4)       X     ( 5, 4)       X     ( 6, 4)       X     ( 7, 4)
X    37.634  F      X    37.634  F      X    36.726  F      X    36.685  F      X    36.740  F      X    36.747  F      X    36.754  F
X  RHS= 3.637E-04 X  RHS= 3.637E-04 X  RHS= 3.523E-04 X  RHS= 3.519E-04 X  RHS= 3.527E-04 X  RHS= 3.528E-04 X  RHS= 3.528E-04
       10        0.0       1       -0.998       1      -0.868       1      -1.050       1      -1.030       1      -0.883       1      -0.741
X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01
X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02
X  CHI= 1.020E-03 X  CHI= 1.020E-03 X  CHI= 1.050E-03 X  CHI= 1.023E-03 X  CHI= 1.006E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03
X  VAP= 2.643E-04 X  VAP= 2.643E-04 X  VAP= 2.495E-04 X  VAP= 2.459E-04 X  VAP= 2.448E-04 X  VAP= 2.449E-04 X  VAP= 2.459E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   3.178 XXXXXXXXX   3.178 XXXXXXXXX   0.221 XXXXXXXXX  -0.361 XXXXXXXXX  -0.307 XXXXXXXXX  -0.309 XXXXXXXXX  -0.320 XXXX
X                   X                   X                   X                   X                   X                   X
X     ( 1, 3)       X     ( 2, 3)       X     ( 3, 3)       X     ( 4, 3)       X     ( 5, 3)       X     ( 6, 3)       X     ( 7, 3)
X    37.780  F      X    37.780  F      X    37.267  F      X    37.017  F      X    36.969  F      X    36.920  F      X    36.858  F
X  RHS= 3.754E-04 X  RHS= 3.754E-04 X  RHS= 3.687E-04 X  RHS= 3.655E-04 X  RHS= 3.648E-04 X  RHS= 3.641E-04 X  RHS= 3.632E-04
       10        0.0       1       -1.307       1      -1.172       1      -1.009       1      -0.912       1      -0.798       1      -0.718
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02
X  CHI= 1.007E-03 X  CHI= 1.007E-03 X  CHI= 1.009E-03 X  CHI= 1.008E-03 X  CHI= 1.003E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03
X  VAP= 2.688E-04 X  VAP= 2.688E-04 X  VAP= 2.613E-04 X  VAP= 2.574E-04 X  VAP= 2.579E-04 X  VAP= 2.585E-04 X  VAP= 2.590E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  3.0019E+02 , CYCLE NUMBER =    95 ,  PRESSURE ITERATION NUMBER =    2 , DT =  3.0408E+00
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XXXXX   1.891 XXXXXXXXX   1.891 XXXXXXXXX   0.367 XXXXXXXXX  -0.188 XXXXXXXXX  -0.196 XXXXXXXXX  -0.179 XXXXXXXXX  -0.223 XXXX
X                  X                  X                  X                  X                  X                  X
X     ( 1, 2)      X     ( 2, 2)      X     ( 3, 2)      X     ( 4, 2)      X     ( 5, 2)      X     ( 6, 2)      X     ( 7, 2)
X   37.863  F      X   37.863  F      X   37.634  F      X   37.530  F      X   37.419  F      X   37.343  F      X   37.260  F
X  RHS= 3.866E-04  X  RHS= 3.866E-04  X  RHS= 3.833E-04  X  RHS= 3.819E-04  X  RHS= 3.803E-04  X  RHS= 3.792E-04  X  RHS= 3.781E-04
      10      0.0        1     -1.895        1     -2.275        1     -2.103        1     -1.923        1     -1.763        1     -1.560
X  TNU= 4.468E-01  X  TNU= 4.468E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01
X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02
X  CHI= 1.004E-03  X  CHI= 1.004E-03  X  CHI= 1.004E-03  X  CHI= 1.004E-03  X  CHI= 1.003E-03  X  CHI= 1.003E-03  X  CHI= 1.002E-03
X  VAP= 2.735E-04  X  VAP= 2.735E-04  X  VAP= 2.724E-04  X  VAP= 2.714E-04  X  VAP= 2.715E-04  X  VAP= 2.718E-04  X  VAP= 2.719E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                  X                  X                  X                  X                  X                  X
X     ( 1, 1)      X     ( 2, 1)      X     ( 3, 1)      X     ( 4, 1)      X     ( 5, 1)      X     ( 6, 1)      X     ( 7, 1)
X   37.863  F      X   37.863  F      X   37.634  F      X   37.530  F      X   37.419  F      X   37.343  F      X   37.260  F
X  RHS= 3.866E-04  X  RHS= 3.866E-04  X  RHS= 3.833E-04  X  RHS= 3.819E-04  X  RHS= 3.803E-04  X  RHS= 3.792E-04  X  RHS= 3.781E-04
       2      1.895     10      1.895     10      2.275     10      2.103     10      1.923     10      1.763     10      1.560
X  TNU= 4.468E-01  X  TNU= 4.468E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01  X  TNU= 4.170E-01
X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02  X  TKE= 4.080E-02
X  CHI= 1.004E-03  X  CHI= 1.004E-03  X  CHI= 1.004E-03  X  CHI= 1.004E-03  X  CHI= 1.003E-03  X  CHI= 1.003E-03  X  CHI= 1.002E-03
X  VAP= 2.735E-04  X  VAP= 2.735E-04  X  VAP= 2.724E-04  X  VAP= 2.714E-04  X  VAP= 2.715E-04  X  VAP= 2.718E-04  X  VAP= 2.719E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
TIME=  3.0019E+02 , CYCLE NUMBER =   95 ,  PRESSURE ITERATION NUMBER =   2 , DT =  3.0408E+00
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PLUME CENTER AT 1726.79 FEET. PLUME SPEED IS   16.50  DOWNWIND DISTANCE IS 4529.
   TOTAL  ENERGY   ON MESH IS   0.73843E+08
TIME=  3.0019E+02 , CYCLE NUMBER =    95 ,  PRESSURE ITERATION NUMBER =   2 , DT =  3.0408E+00 , MAX DIVERGENCE =  5.5035E-04
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XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X               X               X               X               X               X               X
X    ( 1,22)    X    ( 2,22)    X    ( 3,22)    X    ( 4,22)    X    ( 5,22)    X    ( 6,22)    X    ( 7,22)
X   40.004  F   X   40.004  F   X   40.122  F   X   40.372  F   X   40.587  F   X   40.677  F   X   40.704  F
X RHS= 3.724E-04 X RHS= 3.721E-04 X RHS= 3.718E-04 X RHS= 3.720E-04 X RHS= 3.720E-04 X RHS= 3.721E-04 X RHS= 3.625E-04
      2       0.0      10     -1.136     10     -0.920     10     -0.697     10     -0.606     10     -0.658     10     -0.754
X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02
X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02
X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0
X VAP= 1.101E-04 X VAP= 1.101E-04 X VAP= 1.115E-04 X VAP= 1.100E-04 X VAP= 1.083E-04 X VAP= 1.074E-04 X VAP= 1.075E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X               X               X               X               X               X               X
X    ( 1,21)    X    ( 2,21)    X    ( 3,21)    X    ( 4,21)    X    ( 5,21)    X    ( 6,21)    X    ( 7,21)
X   40.004  F   X   40.004  F   X   40.122  F   X   40.372  F   X   40.587  F   X   40.677  F   X   40.704  F
X RHS= 2.530E-04 X RHS= 2.530E-04 X RHS= 2.541E-04 X RHS= 2.566E-04 X RHS= 2.588E-04 X RHS= 2.597E-04 X RHS= 2.600E-04
     10       0.0       1     -1.136      1     -0.920      1     -0.697      1     -0.606      1     -0.658      1     -0.754
X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02 X TNU= 2.100E-02
X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02
X CHI= 9.986E-04 X CHI= 9.986E-04 X CHI= 1.004E-03 X CHI= 9.989E-04 X CHI= 9.977E-04 X CHI= 9.977E-04 X CHI= 9.977E-04
X VAP= 1.101E-04 X VAP= 1.101E-04 X VAP= 1.115E-04 X VAP= 1.100E-04 X VAP= 1.083E-04 X VAP= 1.074E-04 X VAP= 1.075E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -1.229 XXXXXXXXX  -1.229 XXXXXXXXX   0.190 XXXXXXXXX   0.198 XXXXXXXXX   0.068 XXXXXXXXX  -0.074 XXXXXXXXX  -0.117 XXXX
X               X               X               X               X               X               X
X    ( 1,20)    X    ( 2,20)    X    ( 3,20)    X    ( 4,20)    X    ( 5,20)    X    ( 6,20)    X    ( 7,20)
X   39.221  F   X   39.221  F   X   39.083  F   X   39.422  F   X   39.776  F   X   39.928  F   X   39.977  F
X RHS= 2.526E-04 X RHS= 2.526E-04 X RHS= 2.511E-04 X RHS= 2.544E-04 X RHS= 2.579E-04 X RHS= 2.594E-04 X RHS= 2.600E-04
     10       0.0       1      2.296      1      1.802      1      1.087      1      0.515      1      0.115      1     -0.196
X TNU= 7.618E-02 X TNU= 7.618E-02 X TNU= 3.200E-02 X TNU= 3.200E-02 X TNU= 3.200E-02 X TNU= 3.200E-02 X TNU= 3.200E-02
X TKE= 2.200E-02 X TKE= 2.200E-02 X TKE= 2.200E-02 X TKE= 2.200E-02 X TKE= 2.200E-02 X TKE= 2.200E-02 X TKE= 2.200E-02
X CHI= 1.069E-03 X CHI= 1.069E-03 X CHI= 1.053E-03 X CHI= 1.021E-03 X CHI= 1.000E-03 X CHI= 9.976E-04 X CHI= 9.976E-04
X VAP= 1.134E-04 X VAP= 1.134E-04 X VAP= 1.159E-04 X VAP= 1.173E-04 X VAP= 1.161E-04 X VAP= 1.149E-04 X VAP= 1.144E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   0.975 XXXXXXXXX   0.975 XXXXXXXXX  -0.332 XXXXXXXXX  -0.543 XXXXXXXXX  -0.528 XXXXXXXXX  -0.497 XXXXXXXXX  -0.451 XXXX
X       V20     X       V20     X               X               X               X               X
X    ( 1,19)    X    ( 2,19)    X    ( 3,19)    X    ( 4,19)    X    ( 5,19)    X    ( 6,19)    X    ( 7,19)
X   38.514  F   X   38.514  F   X   38.570  F   X   38.452  F   X   38.715  F   X   39.027  F   X   39.221  F
X RHS= 2.494E-04 X RHS= 2.494E-04 X RHS= 2.511E-04 X RHS= 2.510E-04 X RHS= 2.542E-04 X RHS= 2.57(E-04 X RHS= 2.596E-04
     10       0.0       1      4.419      1      5.235      1      4.289      1      2.789      1      1.477      1      0.687
X TNU= 1.573E+00 X TNU= 1.573E+00 X TNU= 7.979E-01 X TNU= 2.800E-01 X TNU= 4.391E-02 X TNU= 2.470E-02 X TNU= 2.470E-02
X TKE= 1.336E-01 X TKE= 1.336E-01 X TKE= 6.364E-02 X TKE= 4.700E-02 X TKE= 4.700E-02 X TKE= 4.700E-02 X TKE= 4.700E-02
X CHI= 2.758E-03 X CHI= 2.758E-03 X CHI= 2.280E-03 X CHI= 1.727E-03 X CHI= 1.280E-03 X CHI= 1.058E-03 X CHI= 1.003E-03
X VAP= 2.101E-04 X VAP= 2.101E-04 X VAP= 1.768E-04 X VAP= 1.490E-04 X VAP= 1.315E-04 X VAP= 1.240E-04 X VAP= 1.217E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   5.308 XXXXXXXXX   5.308 XXXXXXXXX   0.455 XXXXXXXXX  -1.516 XXXXXXXXX  -2.053 XXXXXXXXX  -1.833 XXXXXXXXX  -1.264 XXXX
X       V10     X       V10     X       V10     X       V20     X               X               X
X    ( 1,18)    X    ( 2,18)    X    ( 3,18)    X    ( 4,18)    X    ( 5,18)    X    ( 6,18)    X    ( 7,18)
X   38.556  F   X   38.556  F   X   38.667  F   X   38.320  F   X   38.452  F   X   38.743  F   X   38.965  F
X RHS= 2.559E-04 X RHS= 2.559E-04 X RHS= 2.572E-04 X RHS= 2.550E-04 X RHS= 2.576E-04 X RHS= 2.615E-04 X RHS= 2.642E-04
     10       0.0       1      3.753      1      5.172      1      4.932      1      3.948      1      2.740      1      1.654
X TNU= 1.756E+00 X TNU= 1.756E+00 X TNU= 1.609E+00 X TNU= 1.035E+00 X TNU= 5.320E-01 X TNU= 1.955E-01 X TNU= 5.[illegible]-02
X TKE= 1.287E-01 X TKE= 1.287E-01 X TKE= 1.029E-01 X TKE= 6.338E-02 X TKE= 3.837E-02 X TKE= 2.407E-02 X TKE= 2.400E-02
X CHI= 3.196E-03 X CHI= 3.196E-03 X CHI= 3.504E-03 X CHI= 2.983E-03 X CHI= 2.239E-03 X CHI= 1.567E-03 X CHI= 1.163E-03
X VAP= [illegible]428E-04 X VAP= 2.428E-04 X VAP= 2.371E-04 X VAP= 2.[illegible]E-04 X VAP= 1.709E-04 X VAP= 1.452E-04 X VAP= 1.32[illegible]-04
X LIQ= [illegible]   X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0[illegible]   X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  4.0100E+02 , CYCLE NUMBER =   127 .  PRESSURE ITERATION NUMBER =    6 , DT =  3.2402E+00
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XXXXX   8.986 XXXXXXXXX   8.986 XXXXXXXXX   1.845 XXXXXXXXX  -1.782 XXXXXXXXX  -3.062 XXXXXXXXX  -3.064 XXXXXXXXX  -2.372 XXXX
X           V10        X         V10     X         V10      X         V20      X                X                X
X    ( 1,17)           X     ( 2,17)     X    ( 3,17)       X     ( 4,17)      X    ( 5,17)     X    ( 6,17)     X    ( 7,17)
X    37.863   F        X    37.863   F   X   38.611   F     X    38.306   F    X   38.313   F   X   38.466   F   X   38.584   F
X  RHS= 2.565E-04      X RHS= 2.565E-04  X RHS= 2.637E-04   X RHS= 2.613E-04  X RHS= 2.627E-04 X RHS= 2.654E-04 X RHS= 2.674E-04
      10        0.0        1       2.487      1       3.620       1       3.890     1       3.567    1       2.890    1       2.060
X  TNU= 1.317E+00      X TNU= 1.317E+00  X TNU= 1.643E+00   X TNU= 1.252E+00  X TNU= 7.849E-01 X TNU= 3.953E-01 X TNU= 1.860E-01
X  TKE= 7.753E-02      X TKE= 7.753E-02  X TKE= 9.567E-02   X TKE= 6.502E-02  X TKE= 4.069E-02 X TKE= 2.557E-02 X TKE= 2.550E-02
X  CHI= 3.202E-03      X CHI= 3.202E-03  X CHI= 4.258E-03   X CHI= 3.852E-03  X CHI= 3.056E-03 X CHI= 2.198E-03 X CHI= 1.537E-03
X  VAP= 2.413E-04      X VAP= 2.413E-04  X VAP= 2.478E-04   X VAP= 2.300E-04  X VAP= 1.969E-04 X VAP= 1.658E-04 X VAP= 1.456E-04
X  LIQ= 0.0            X LIQ= 0.0        X LIQ= 0.0         X LIQ= 0.0        X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  11.413 XXXXXXXXX  11.413 XXXXXXXXX   2.951 XXXXXXXXX  -1.536 XXXXXXXXX  -3.408 XXXXXXXXX  -3.763 XXXXXXXXX  -3.223 XXXX
X           V10        X         V10     X         V10      X         V10      X                X                X
X    ( 1,16)           X     ( 2,16)     X    ( 3,16)       X     ( 4,16)      X    ( 5,16)     X    ( 6,16)     X    ( 7,16)
X    37.038   F        X    37.038   F   X   37.884   F     X    37.994   F    X   38.133   F   X   38.258   F   X   38.327   F
X  RHS= 2.559E-04      X RHS= 2.559E-04  X RHS= 2.639E-04   X RHS= 2.654E-04  X RHS= 2.680E-04 X RHS= 2.705E-04 X RHS= 2.721E-04
      10        0.0        1       0.995      1       1.477       1       2.105     1       2.389    1       2.277    1       1.869
X  TNU= 1.119E+00      X TNU= 1.119E+00  X TNU= 1.746E+00   X TNU= 1.321E+00  X TNU= 8.786E-01 X TNU= 5.065E-01 X TNU= 2.758E-01
X  TKE= 5.863E-02      X TKE= 5.863E-02  X TKE= 9.956E-02   X TKE= 6.280E-02  X TKE= 3.963E-02 X TKE= 2.700E-02 X TKE= 2.700E-02
X  CHI= 3.241E-03      X CHI= 3.241E-03  X CHI= 5.412E-03   X CHI= 4.819E-03  X CHI= 3.830E-03 X CHI= 2.817E-03 X CHI= 1.988E-03
X  VAP= 2.394E-04      X VAP= 2.394E-04  X VAP= 2.499E-04   X VAP= 2.411E-04  X VAP= 2.115E-04 X VAP= 1.802E-04 X VAP= 1.575E-04
X  LIQ= 0.0            X LIQ= 0.0        X LIQ= 0.0         X LIQ= 0.0        X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  12.368 XXXXXXXXX  12.368 XXXXXXXXX   3.410 XXXXXXXXX  -0.929 XXXXXXXXX  -3.145 XXXXXXXXX  -3.893 XXXXXXXXX  -3.649 XXXX
X           V10        X         V10     X         V10      X         V10      X       V20      X                X
X    ( 1,15)           X     ( 2,15)     X    ( 3,15)       X     ( 4,15)      X    ( 5,15)     X    ( 6,15)     X    ( 7,15)
X    36.560   F        X    36.560   F   X   37.114   F     X    37.606   F    X   37.897   F   X   38.022   F   X   38.057   F
X  RHS= 2.584E-04      X RHS= 2.584E-04  X RHS= 2.635E-04   X RHS= 2.685E-04  X RHS= 2.727E-04 X RHS= 2.752E-04 X RHS= 2.765E-04
      10        0.0        1      -0.546      1      -0.486       1       0.517     1       1.182    1       1.467    1       1.468
X  TNU= 1.076E+00      X TNU= 1.076E+00  X TNU= 1.849E+00   X TNU= 1.315E+00  X TNU= 8.879E-01 X TNU= 5.509E-01 X TNU= 3.281E-01
X  TKE= 5.598E-02      X TKE= 5.598E-02  X TKE= 1.059E-01   X TKE= 5.677E-02  X TKE= 3.602E-02 X TKE= 2.770E-02 X TKE= 2.770E-02
X  CHI= 3.347E-03      X CHI= 3.347E-03  X CHI= 6.712E-03   X CHI= 6.064E-03  X CHI= 4.643E-03 X CHI= 3.445E-03 X CHI= 2.487E-03
X  VAP= 2.382E-04      X VAP= 2.382E-04  X VAP= 2.499E-04   X VAP= 2.500E-04  X VAP= 2.205E-04 X VAP= 1.903E-04 X VAP= 1.677E-04
X  LIQ= 0.0            X LIQ= 0.0        X LIQ= 0.0         X LIQ= 0.0        X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  11.802 XXXXXXXXX  11.802 XXXXXXXXX   3.455 XXXXXXXXX   0.059 XXXXXXXXX  -2.496 XXXXXXXXX  -3.624 XXXXXXXXX  -3.663 XXXX
X           V20        X         V20     X         V10      X         V10      X       V20      X                X
X    ( 1,14)           X     ( 2,14)     X    ( 3,14)       X     ( 4,14)      X    ( 5,14)     X    ( 6,14)     X    ( 7,14)
X    36.463   F        X    36.463   F   X   36.740   F     X    37.121   F    X   37.648   F   X   37.814   F   X   37.877   F
X  RHS= 2.649E-04      X RHS= 2.649E-04  X RHS= 2.674E-04   X RHS= 2.708E-04  X RHS= 2.776E-04 X RHS= 2.806E-04 X RHS= 2.821E-04
      10        0.0        1      -1.413      1      -1.329       1      -0.332     1       0.300    1       0.736    1       1.034
X  TNU= 1.055E+00      X TNU= 1.055E+00  X TNU= 1.643E+00   X TNU= 1.228E+00  X TNU= 8.618E-01 X TNU= 5.529E-01 X TNU= 3.880E-01
X  TKE= 5.591E-02      X TKE= 5.591E-02  X TKE= 9.076E-02   X TKE= 4.842E-02  X TKE= 3.162E-02 X TKE= 2.930E-02 X TKE= 2.930E-02
X  CHI= 3.423E-03      X CHI= 3.423E-03  X CHI= 7.247E-03   X CHI= 8.391E-03  X CHI= 5.653E-03 X CHI= 4.126E-03 X CHI= 3.039E-03
X  VAP= 2.371E-04      X VAP= 2.371E-04  X VAP= 2.464E-04   X VAP= 2.601E-04  X VAP= 2.287E-04 X VAP= 1.986E-04 X VAP= 1.770E-04
X  LIQ= 0.0            X LIQ= 0.0        X LIQ= 0.0         X LIQ= 0.0        X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  10.385 XXXXXXXXX  10.385 XXXXXXXXX   3.529 XXXXXXXXX   1.046 XXXXXXXXX  -1.872 XXXXXXXXX  -3.196 XXXXXXXXX  -3.374 XXXX
X           V20        X         V20     X         V20      X         V20      X       V20      X                X
X    ( 1,13)           X     ( 2,13)     X    ( 3,13)       X     ( 4,13)      X    ( 5,13)     X    ( 6,13)     X    ( 7,13)
X    36.754   F        X    36.754   F   X   36.872   F     X    36.969   F    X   37.392   F   X   37.599   F   X   37.690   F
X  RHS= 2.757E-04      X RHS= 2.757E-04  X RHS= 2.768E-04   X RHS= 2.774E-04  X RHS= 2.825E-04 X RHS= 2.860E-04 X RHS= 2.878E-04
      10        0.0        1      -1.487      1      -1.370       1      -1.070     1      -0.411    1       0.127    1       0.593
X  TNU= 9.322E-01      X TNU= 9.322E-01  X TNU= 1.264E+00   X TNU= 8.915E-01  X TNU= 8.143E-01 X TNU= 5.211E-01 X TNU= 4.350E-01
X  TKE= 4.828E-02      X TKE= 4.828E-02  X TKE= 6.583E-02   X TKE= 3.279E-02  X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02
X  CHI= 3.105E-03      X CHI= 3.105E-03  X CHI= 6.649E-03   X CHI= 8.395E-03  X CHI= 6.674E-03 X CHI= 4.748E-03 X CHI= 3.518E-03
X  VAP= 2.352E-04      X VAP= 2.352E-04  X VAP= 2.368E-04   X VAP= 2.492E-04  X VAP= 2.356E-04 X VAP= 2.050E-04 X VAP= 1.844E-04
X  LIQ= 0.0            X LIQ= 0.0        X LIQ= 0.0         X LIQ= 0.0        X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  4.0100E+02 , CYCLE NUMBER =  127 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.2402E+00
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XXXXX   8.915 XXXXXXXXX   8.915 XXXXXXXXX   3.638 XXXXXXXXX   1.341 XXXXXXXXX  -1.218 XXXXXXXXX  -2.663 XXXXXXXXX  -2.913 XXXX
X          V20    X          V20    X                 X          V20    X          V20    X                 X
X     ( 1,12)     X     ( 2,12)     X     ( 3,12)     X     ( 4,12)     X     ( 5,12)     X     ( 6,12)     X     ( 7,12)
X   37.080   F    X   37.080   F    X   36.955   F    X   37.107   F    X   37.308   F    X   37.530   F    X   37.634   F
X  RHS= 2.871E-04 X  RHS= 2.871E-04 X  RHS= 2.861E-04 X  RHS= 2.874E-04 X  RHS= 2.897E-04 X  RHS= 2.931E-04 X  RHS= 2.952E-04
      10      0.0         1     -1.421        1     -1.564        1     -1.577        1     -0.993        1     -0.401        1      0.164
X  TNU= 7.998E-01 X  TNU= 7.998E-01 X  TNU= 9.440E-01 X  TNU= 6.417E-01 X  TNU= 6.571E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01
X  TKE= 4.010E-02 X  TKE= 4.010E-02 X  TKE= 4.729E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02
X  CHI= 2.613E-03 X  CHI= 2.613E-03 X  CHI= 5.417E-03 X  CHI= 7.136E-03 X  CHI= 6.967E-03 X  CHI= 5.147E-03 X  CHI= 3.686E-03
X  VAP= 2.335E-04 X  VAP= 2.335E-04 X  VAP= 2.253E-04 X  VAP= 2.340E-04 X  VAP= 2.330E-04 X  VAP= 2.088E-04 X  VAP= 1.886E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   7.531 XXXXXXXXX   7.531 XXXXXXXXX   3.493 XXXXXXXXX   1.327 XXXXXXXXX  -0.635 XXXXXXXXX  -2.072 XXXXXXXXX  -2.348 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1,11)     X     ( 2,11)     X     ( 3,11)     X     ( 4,11)     X     ( 5,11)     X     ( 6,11)     X     ( 7,11)
X   37.364   F    X   37.364   F    X   37.142   F    X   37.184   F    X   37.322   F    X   37.412   F    X   37.489   F
X  RHS= 2.984E-04 X  RHS= 2.984E-04 X  RHS= 2.967E-04 X  RHS= 2.970E-04 X  RHS= 2.985E-04 X  RHS= 3.002E-04 X  RHS= 3.018E-04
      10      0.0         1     -1.320        1     -1.623        1     -1.746        1     -1.389        1     -0.804        1     -0.214
X  TNU= 6.991E-01 X  TNU= 6.991E-01 X  TNU= 7.717E-01 X  TNU= 5.218E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01
X  TKE= 3.439E-02 X  TKE= 3.439E-02 X  TKE= 3.809E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02
X  CHI= 2.124E-03 X  CHI= 2.124E-03 X  CHI= 4.108E-03 X  CHI= 5.559E-03 X  CHI= 5.999E-03 X  CHI= 4.778E-03 X  CHI= 3.336E-03
X  VAP= 2.334E-04 X  VAP= 2.334E-04 X  VAP= 2.156E-04 X  VAP= 2.189E-04 X  VAP= 2.200E-04 X  VAP= 2.053E-04 X  VAP= 1.881E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  L.Q= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   6.269 XXXXXXXXX   6.269 XXXXXXXX(   3.194 XXXXXXXXX   1.206 XXXXXXXXX  -0.276 XXXXXXXXX  -1.484 XXXXXXXXX  -1.754 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1,10)     X     ( 2,10)     X     ( 3,10)     X     ( 4,10)     X     ( 5,10)     X     ( 6,10)     X     ( 7,10)
X   37.392   F    X   37.392   F    X   37.232   F    X   37.191   F    X   37.281   F    X   37.343   F    X   37.364   F
X  RHS= 3.071E-04 X  RHS= 3.071E-04 X  RHS= 3.064E-04 X  RHS= 3.061E-04 X  RHS= 3.072E-04 X  RHS= 3.082E-04 X  RHS= 3.090E-04
      10      0.0         1     -1.144        1     -1.533        1     -1.680        1     -1.560        1     -1.070        1     -0.575
X  TNU= 6.236E-01 X  TNU= 6.236E-01 X  TNU= 6.983E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01
X  TKE= 3.097E-02 X  TKE= 3.097E-02 X  TKE= 3.321E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02
X  CHI= 1.712E-03 X  CHI= 1.712E-03 X  CHI= 2.939E-03 X  CHI= 3.824E-03 X  CHI= 4.225E-03 X  CHI= 3.646E-03 X  CHI= 2.485E-03
X  VAP= 2.352E-04 X  VAP= 2.352E-04 X  VAP= 2.093E-04 X  VAP= 2.055E-04 X  VAP= 2.042E-04 X  VAP= 1.967E-04 X  VAP= 1.847E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   5.193 XXXXXXXXX   5.193 XXXXXXXXX   2.820 XXXXXXXXX   1.071 XXXXXXXXX  -0.147 XXXXXXXXX  -0.986 XXXXXXXXX  -1.253 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1, 9)     X     ( 2, 9)     X     ( 3, 9)     X     ( 4, 9)     X     ( 5, 9)     X     ( 6, 9)     X     ( 7, 9)
X   37.350   F    X   37.350   F    X   37.204   F    X   37.156   F    X   37.128   F    X   37.163   F    X   37.135   F
X  RHS= 3.151E-04 X  RHS= 3.151E-04 X  RHS= 3.148E-04 X  RHS= 3.146E-04 X  RHS= 3.144E-04 X  RHS= 3.150E-04 X  RHS= 3.150E-04
      10      0.0         1     -0.914        1     -1.439        1     -1.608        1     -1.572        1     -1.272        1     -0.952
X  TNU= 5.664E-01 X  TNU= 5.664E-01 X  TNU= 6.373E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01
X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02
X  CHI= 1.418E-03 X  CHI= 1.418E-03 X  CHI= 2.114E-03 X  CHI= 2.477E-03 X  CHI= 2.664E-03 X  CHI= 2.37 E-03 X  CHI= 1.668E-03
X  VAP= 2.391E-04 X  VAP= 2.391E-04 X  VAP= 2.077E-04 X  VAP= 1.987E-04 X  VAP= 1.946E-04 X  VAP= 1.901E-04 X  VAP= 1.841E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   4.352 XXXXXXXXX   4.352 XXXXXXXXX   2.315 XXXXXXXXX   0.918 XXXXXXXXX  -0.096 XXXXXXXXX  -0.673 XXXXXXXXX  -0.921 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1, 8)     X     ( 2, 8)     X     ( 3, 8)     X     ( 4, 8)     X     ( 5, 8)     X     ( 6, 8)     X     ( 7, 8)
X   37.281   F    X   37.281   F    X   37.087   F    X   37.080   F    X   37.052   F    X   36.996   F    X   36.955   F
X  RHS= 3.229E-04 X  RHS= 3.229E-04 X  RHS= 3.221E-04 X  RHS= 3.225E-04 X  RHS= 3.224E-04 X  RHS= 3.219E-04 X  RHS= 3.214E-04
      10      0.0         1     -0.643        1     -1.302        1     -1.599        1     -1.620        1     -1.464        1     -1.254
X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.637E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01
X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02
X  CHI= 1.232E-03 X  CHI= 1.232E-03 X  CHI= 1.617E-03 X  CHI= 1.675E-03 X  CHI= 1.698E-03 X  CHI= 1.537E-03 X  CHI= 1.223E-03
X  VAP= 2.447E-04 X  VAP= 2.447E-04 X  VAP= 2.106E-04 X  VAP= 1.992E-04 X  VAP= 1.937E-04 X  VAP= 1.910E-04 X  VAP= 1.89[illegible]E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.(
TIME=  4.0100E+02 , CYCLE NUMBER =   127 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.2402E+00
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XXXXX   3.778 XXXXXXXXX   3.778 XXXXXXXXX   1.679 XXXXXXXXX   0.641 XXXXXXXXX  -0.099 XXXXXXXXX  -0.501 XXXXXXXXX  -0.696 XXXX
X                X                X                X                X                X                X
X     ( 1, 7)    X     ( 2, 7)    X     ( 3, 7)    X     ( 4, 7)    X     ( 5, 7)    X     ( 6, 7)    X     ( 7, 7)
X    37.294  F   X    37.294  F   X    36.934  F   X    36.927  F   X    36.941  F   X    36.948  F   X    36.913  F
X  RHS= 3.316E-04 X  RHS= 3.316E-04 X  RHS= 3.287E-04 X  RHS= 3.292E-04 X  RHS= 3.296E-04 X  RHS= 3.298E-04 X  RHS= 3.293E-04
      10       0.0       1       -0.398      1       -1.091      1       -1.435      1       -1.531      1       -1.470      1       -1.311
X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01
X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 1.124E-03 X  CHI= 1.124E-03 X  CHI= 1.347E-03 X  CHI= 1.280E-03 X  CHI= 1.252E-03 X  CHI= 1.174E-03 X  CHI= 1.060E-03
X  VAP= 2.510E-04 X  VAP= 2.510E-04 X  VAP= 2.172E-04 X  VAP= 2.063E-04 X  VAP= 2.010E-04 X  VAP= 1.994E-04 X  VAP= 2.003E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   3.442 XXXXXXXXX   3.442 XXXXXXXXX   1.008 XXXXXXXXX   0.319 XXXXXXXXX  -0.175 XXXXXXXXX  -0.421 XXXXXXXXX  -0.520 XXXX
X                X                X                X                X                X                X
X     ( 1, 6)    X     ( 2, 6)    X     ( 3, 6)    X     ( 4, 6)    X     ( 5, 6)    X     ( 6, 6)    X     ( 7, 6)
X    37.378  F   X    37.378  F   X    36.893  F   X    36.837  F   X    36.802  F   X    36.809  F   X    36.816  F
X  RHS= 3.416E-04 X  RHS= 3.416E-04 X  RHS= 3.369E-04 X  RHS= 3.366E-04 X  RHS= 3.364E-04 X  RHS= 3.365E-04 X  RHS= 3.365E-04
      10       0.0       1       -0.255      1       -0.932      1       -1.182      1       -1.226      1       -1.190      1       -1.086
X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01
X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02
X  CHI= 1.063E-03 X  CHI= 1.063E-03 X  CHI= 1.203E-03 X  CHI= 1.112E-03 X  CHI= 1.085E-03 X  CHI= 1.050E-03 X  CHI= 1.013E-03
X  VAP= 2.566E-04 X  VAP= 2.566E-04 X  VAP= 2.259E-04 X  VAP= 2.182E-04 X  VAP= 2.137E-04 X  VAP= 2.126E-04 X  VAP= 2.145E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   3.239 XXXXXXXXX   3.239 XXXXXXXXX   0.354 XXXXXXXXX   0.090 XXXXXXXXX  -0.200 XXXXXXXXX  -0.366 XXXXXXXXX  -0.398 XXXX
X                X                X                X                X                X                X
X     ( 1, 5)    X     ( 2, 5)    X     ( 3, 5)    X     ( 4, 5)    X     ( 5, 5)    X     ( 6, 5)    X     ( 7, 5)
X    37.412  F   X    37.412  F   X    36.782  F   X    36.823  F   X    36.802  F   X    36.754  F   X    36.733  F
X  RHS= 3.513E-04 X  RHS= 3.513E-04 X  RHS= 3.443E-04 X  RHS= 3.450E-04 X  RHS= 3.449E-04 X  RHS= 3.443E-04 X  RHS= 3.440E-04
      10       0.0       1       -0.274      1       -0.725      1       -1.011      1       -0.981      1       -0.913      1       -0.829
X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01
X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02
X  CHI= 1.031E-03 X  CHI= 1.031E-03 X  CHI= 1.105E-03 X  CHI= 1.038E-03 X  CHI= 1.024E-03 X  CHI= 1.012E-03 X  CHI= 1.003E-03
X  VAP= 2.609E-04 X  VAP= 2.609E-04 X  VAP= 2.360E-04 X  VAP= 2.317E-04 X  VAP= 2.283E-04 X  VAP= 2.276E-04 X  VAP= 2.293E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   3.006 XXXXXXXXX   3.006 XXXXXXXXX  -0.077 XXXXXXXXX  -0.176 XXXXXXXXX  -0.152 XXXXXXXXX  -0.279 XXXXXXXXX  -0.297 XXXX
X                X                X                X                X                X                X
X     ( 1, 4)    X     ( 2, 4)    X     ( 3, 4)    X     ( 4, 4)    X     ( 5, 4)    X     ( 6, 4)    X     ( 7, 4)
X    37.461  F   X    37.461  F   X    36.671  F   X    36.588  F   X    36.671  F   X    36.650  F   X    36.657  F
X  RHS= 3.613E-04 X  RHS= 3.613E-04 X  RHS= 3.515E-04 X  RHS= 3.507E-04 X  RHS= 3.519E-04 X  RHS= 3.516E-04 X  RHS= 3.517E-04
      10       0.0       1       -0.545      1       -0.228      1       -0.527      1       -0.590      1       -0.541      1       -0.473
X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01
X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02
X  CHI= 1.014E-03 X  CHI= 1.014E-03 X  CHI= 1.036E-03 X  CHI= 1.017E-03 X  CHI= 1.006E-03 X  CHI= 1.003E-03 X  CHI= 1.001E-03
X  VAP= 2.645E-04 X  VAP= 2.645E-04 X  VAP= 2.497E-04 X  VAP= 2.442E-04 X  VAP= 2.429E-04 X  VAP= 2.423E-04 X  VAP= 2.435E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   2.492 XXXXXXXXX   2.492 XXXXXXXXX   0.258 XXXXXXXXX  -0.459 XXXXXXXXX  -0.198 XXXXXXXXX  -0.213 XXXXXXXXX  -0.212 XXXX
X                X                X                X                X                X                X
X     ( 1, 3)    X     ( 2, 3)    X     ( 3, 3)    X     ( 4, 3)    X     ( 5, 3)    X     ( 6, 3)    X     ( 7, 3)
X    37.551  F   X    37.551  F   X    37.066  F   X    36.830  F   X    36.802  F   X    36.754  F   X    36.698  F
X  RHS= 3.723E-04 X  RHS= 3.723E-04 X  RHS= 3.660E-04 X  RHS= 3.631E-04 X  RHS= 3.626E-04 X  RHS= 3.620E-04 X  RHS= 3.612E-04
      10       0.0       1       -0.916      1       -0.763      1       -0.548      1       -0.538      1       -0.495      1       -0.471
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02
X  CHI= 1.006E-03 X  CHI= 1.006E-03 X  CHI= 1.007E-03 X  CHI= 1.008E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03 X  CHI= 1.001E-03
X  VAP= 2.683E-04 X  VAP= 2.683E-04 X  VAP= 2.610E-04 X  VAP= 2.551E-04 X  VAP= 2.563E-04 X  VAP= 2.567E-04 X  VAP= 2.573E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  4.0100E+02 , CYCLE NUMBER =  127 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.2402E+00
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XXXXX   1.598 XXXXXXXXX   1.598 XXXXXXXXX   0.424 XXXXXXXXX  -0.229 XXXXXXXXX  -0.173 XXXXXXXXX  -0.156 XXXXXXXXX  -0.174 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1, 2)     X     ( 2, 2)     X     ( 3, 2)     X     ( 4, 2)     X     ( 5, 2)     X     ( 6, 2)     X     ( 7, 2)
X    37.780  F    X    37.780  F    X    37.412  F    X    37.329  F    X    37.260  F    X    37.197  F    X    37.149  F
X  RHS= 3.854E-04 X  RHS= 3.854E-04 X  RHS= 3.803E-04 X  RHS= 3.792E-04 X  RHS= 3.782E-04 X  RHS= 3.773E-04 X  RHS= 3.766E-04
        10       0.0        1      -1.615       1      -2.057       1      -1.849       1      -1.700       1      -1.570       1      -1.425
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.004E-03 X  CHI= 1.004E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.002E-03 X  CHI= 1.002E-03
X  VAP= 2.723E-04 X  VAP= 2.723E-04 X  VAP= 2.710E-04 X  VAP= 2.700E-04 X  VAP= 2.704E-04 X  VAP= 2.707E-04 X  VAP= 2.709E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1, 1)     X     ( 2, 1)     X     ( 3, 1)     X     ( 4, 1)     X     ( 5, 1)     X     ( 6, 1)     X     ( 7, 1)
X    37.780  F    X    37.780  F    X    37.412  F    X    37.329  F    X    37.260  F    X    37.197  F    X    37.149  F
X  RHS= 3.854E-04 X  RHS= 3.854E-04 X  RHS= 3.803E-04 X  RHS= 3.792E-04 X  RHS= 3.782E-04 X  RHS= 3.773E-04 X  RHS= 3.766E-04
         2       1.615     10       1.615     10       2.057     10       1.849     10       1.700     10       1.570     10       1.425
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.004E-03 X  CHI= 1.004E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.002E-03 X  CHI= 1.002E-03
X  VAP= 2.723E-04 X  VAP= 2.723E-04 X  VAP= 2.710E-04 X  VAP= 2.700E-04 X  VAP= 2.704E-04 X  VAP= 2.707E-04 X  VAP= 2.709E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  4.0100E+02 , CYCLE NUMBER =  127    PRESSURE ITERATION NUMBER =    6 , DT =  3.2402E+00
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PLUME CENTER AT 1751.63 FEET. PLUME SPEED IS   16.64  DOWNWIND DISTANCE IS 6200.
   TOTAL  ENERGY   ON MESH IS   0.73844E+08
TIME=  4.0100E+02 , CYCLE NUMBER =  127 ,  PRESSURE ITERATION NUMBER =   6 , DT =  3.2402E+00 , MAX DIVERGENCE =  5.6526E-04
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XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                 X                 X                 X                 X                 X
X    ( 1,22)     X    ( 2,22)      X    ( 3,22)      X    ( 4,22)      X    ( 5,22)      X    ( 6,22)      X    ( 7,22)
X   42.375  F    X   42.375  F     X   40.753  F     X   40.940  F     X   41.093  F     X   41.148  F     X   41.162  F
X  RHS= 3.726E-04 X  RHS= 3.721E-04 X  RHS= 3.721E-04 X  RHS= 3.723E-04 X  RHS= 3.726E-04 X  RHS= 3.728E-04 X  RHS= 3.625E-04
      2      0.0      10      1.023     10      0.087     10     -1.038     10     -1.613     10     -1.621     10     -1.597
X  TNU= 9.289E-02 X  TNU= 9.289E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0
X  VAP= 1.158E-04 X  VAP= 1.158E-04 X  VAP= 1.112E-04 X  VAP= 1.093E-04 X  VAP= 1.080E-04 X  VAP= 1.076E-04 X  VAP= 1.076E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXXXXXXX    0.0    XXXX
X                X                 X                 X                 X                 X                 X
X    ( 1,21)     X    ( 2,21)      X    ( 3,21)      X    ( 4,21)      X    ( 5,21)      X    ( 6,21)      X    ( 7,21)
X   42.375  F    X   42.375  F     X   40.753  F     X   40.940  F     X   41.093  F     X   41.148  F     X   41.162  F
X  RHS= 2.767E-04 X  RHS= 2.767E-04 X  RHS= 2.603E-04 X  RHS= 2.622E-04 X  RHS= 2.638E-04 X  RHS= 2.644E-04 X  RHS= 2.645E-04
     10      0.0       1      1.023      1      0.087      1     -1.038      1     -1.613      1     -1.621      1     -1.597
X  TNU= 9.289E-02 X  TNU= 9.289E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 1.095E-03 X  CHI= 1.095E-03 X  CHI= 1.008E-03 X  CHI= 1.000E-03 X  CHI= 9.988E-04 X  CHI= 9.987E-04 X  CHI= 9.987E-04
X  VAP= 1.158E-04 X  VAP= 1.158E-04 X  VAP= 1.112E-04 X  VAP= 1.093E-04 X  VAP= 1.080E-04 X  VAP= 1.076E-04 X  VAP= 1.076E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    1.009 XXXXXXXXX    1.009 XXXXXXXXX   -0.944 XXXXXXXXX   -1.132 XXXXXXXXX   -0.582 XXXXXXXXX   -0.014 XXXXXXXXX    0.017 XXXX
X                X                 X                 X                 X                 X                 X
X    ( 1,20)     X    ( 2,20)      X    ( 3,20)      X    ( 4,20)      X    ( 5,20)      X    ( 6,20)      X    ( 7,20)
X   41.515  F    X   41.515  F     X   39.741  F     X   39.526  F     X   39.796  F     X   40.254  F     X   40.441  F
X  RHS= 2.717E-04 X  RHS= 2.717E-04 X  RHS= 2.556E-04 X  RHS= 2.546E-04 X  RHS= 2.578E-04 X  RHS= 2.627E-04 X  RHS= 2.646E-04
     10      0.0       1      3.908      1      4.441      1      3.426      1      1.470      1     -0.430      1     -1.026
X  TNU= 2.120E+00 X  TNU= 2.120E+00 X  TNU= 1.132E+00 X  TNU= 4.974E-01 X  TNU= 1.273E-01 X  TNU= 3.200E-02 X  TNU= 3.200E-02
X  TKE= 1.660E-01 X  TKE= 1.660E-01 X  TKE= 8.200E-02 X  TKE= 3.717E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02
X  CHI= 3.002E-03 X  CHI= 3.002E-03 X  CHI= 2.069E-03 X  CHI= 1.507E-03 X  CHI= 1.173E-03 X  CHI= 1.019E-03 X  CHI= 9.987E-04
X  VAP= 2.141E-04 X  VAP= 2.141E-04 X  VAP= 1.687E-04 X  VAP= 1.394E-04 X  VAP= 1.229E-04 X  VAP= 1.159E-04 X  VAP= 1.146E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    4.902 XXXXXXXXX    4.902 XXXXXXXXX   -0.414 XXXXXXXXX   -2.153 XXXXXXXXX   -2.545 XXXXXXXXX   -1.921 XXXXXXXXX   -0.584 XXXX
X        V20     X        V20      X        V20      X                 X                 X                 X
X    ( 1,19)     X    ( 2,19)      X    ( 3,19)      X    ( 4,19)      X    ( 5,19)      X    ( 6,19)      X    ( 7,19)
X   41.439  F    X   41.439  F     X   39.547  F     X   39.173  F     X   39.339  F     X   39.533  F     X   39.575  F
X  RHS= 2.777E-04 X  RHS= 2.777E-04 X  RHS= 2.586E-04 X  RHS= 2.562E-04 X  RHS= 2.590E-04 X  RHS= 2.617E-04 X  RHS= 2.627E-04
     10      0.0       1      3.184      1      4.619      1      4.473      1      3.562      1      2.354      1      0.925
X  TNU= 1.919E+00 X  TNU= 1.919E+00 X  TNU= 2.015E+00 X  TNU= 1.365E+00 X  TNU= 7.916E-01 X  TNU= 3.65[illegible]E-01 X  TNU= 6.011E-02
X  TKE= 1.211E-01 X  TKE= 1.211E-01 X  TKE= 1.223E-01 X  TKE= 7.794E-02 X  TKE= 4.771E-02 X  TKE= 4.70[illegible]E-02 X  TKE= 4.700E-02
X  CHI= 3.714E-03 X  CHI= 3.714E-03 X  CHI= 3.473E-03 X  CHI= 2.673E-03 X  CHI= 2.025E-03 X  CHI= 1.61[illegible]E-03 X  CHI= 1.299E-03
X  VAP= 2.392E-04 X  VAP= 2.392E-04 X  VAP= 2.321E-04 X  VAP= 1.981E-04 X  VAP= 1.673E-04 X  VAP= 1.470E-04 X  VAP= 1.329E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    8.066 XXXXXXXXX    8.066 XXXXXXXXX    1.017 XXXXXXXXX   -2.306 XXXXXXXXX   -3.460 XXXXXXXXX   -3.132 XXXXXXXXX   -2.018 XXXX
X        V20     X        V20      X        V10      X        V20      X                 X                 X
X    ( 1,18)     X    ( 2,18)      X    ( 3,18)      X    ( 4,18)      X    ( 5,18)      X    ( 6,18)      X    ( 7,18)
X   40.919  F    X   40.919  F     X   39.547  F     X   39.090  F     X   39.069  F     X   39.124  F     X   39.221  F
X  RHS= 2.803E-04 X  RHS= 2.803E-04 X  RHS= 2.658E-04 X  RHS= 2.619E-04 X  RHS= 2.628E-04 X  RHS= 2.643E-04 X  RHS= 2.661E-04
     10      0.0       1      1.929      1      3.074      1      3.446      1      3.211      1      2.596      1      1.848
X  TNU= 1.450E+00 X  TNU= 1.450E+00 X  TNU= 1.982E+00 X  TNU= 1.552E+00 X  TNU= 1.050E+00 X  TNU= 5.991E-01 X  TNU= 2.571E-01
X  TKE= 7.035E-02 X  TKE= 7.035E-02 X  TKE= 1.024E-01 X  TKE= 7.505E-02 X  TKE= 5.117E-02 X  TKE= 3.792E-02 X  TKE= 2.[illegible]E-02
X  CHI= 3.902E-03 X  CHI= 3.902E-03 X  CHI= 4.405E-03 X  CHI= 3.492E-03 X  CHI= 2.695E-03 X  CHI= 2.121E-03 X  CHI= 1.661E-03
X  VAP= 2.382E-04 X  VAP= 2.382E-04 X  VAP= 2.426E-04 X  VAP= 2.231E-04 X  VAP= 1.947E-04 X  VAP= 1.698E-04 X  VAP= 1.496E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  5 [illegible]0E+02 , CYCLE NUMBER =  154 ,  PRESSURE ITERATION NU[illegible] =   4 , DT =  3.9186E+00
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XXXXX   9.959 XXXXXXXXX   9.959 XXXXXXXXX   2.165 XXXXXXXXX  -1.936 XXXXXXXXX  -3.700 XXXXXXXXX  -3.755 XXXXXXXXX  -2.774 XXXX
X         V20    X          V20    X          V10    X          V20    X                 X                 X
X    ( 1,17)     X    ( 2,17)      X    ( 3,17)      X    ( 4,17)      X    ( 5,17)      X    ( 6,17)      X    ( 7,17)
X    39.561  F   X    39.561  F    X    39.117  F    X    39.076  F    X    38.965  F    X    38.979  F    X    39.090  F
X  RHS= 2.739E-04 X  RHS= 2.739E-04 X  RHS= 2.690E-04 X  RHS= 2.691E-04 X  RHS= 2.689E-04 X  RHS= 2.701E-04 X  RHS= 2.721E-04
     10       0.0       1       0.511       1       0.683       1       1.503       1       1.910       1       1.983       1       1.855
X  TNU= 1.280E+00 X  TNU= 1.280E+00 X  TNU= 2.076E+00 X  TNU= 1.543E+00 X  TNU= 1.074E+00 X  TNU= 6.663E-01 X  TNU= 3.398E-01
X  TKE= 5.709E-02 X  TKE= 5.709E-02 X  TKE= 1.017E-01 X  TKE= 6.605E-02 X  TKE= 4.567E-02 X  TKE= 3.230E-02 X  TKE= 2.550E-02
X  CHI= 3.994E-03 X  CHI= 3.994E-03 X  CHI= 5.448E-03 X  CHI= 4.028E-03 X  CHI= 3.109E-03 X  CHI= 2.457E-03 X  CHI= 1.938E-03
X  VAP= 2.365E-04 X  VAP= 2.365E-04 X  VAP= 2.450E-04 X  VAP= 2.323E-04 X  VAP= 2.068E-04 X  VAP= 1.815E-04 X  VAP= 1.601E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  10.402 XXXXXXXXX  10.402 XXXXXXXXX   2.338 XXXXXXXXX  -1.117 XXXXXXXXX  -3.296 XXXXXXXXX  -3.686 XXXXXXXXX  -2.905 XXXX
X         V20    X          V20    X          V10    X          V20    X                 X                 X
X    ( 1,16)     X    ( 2,16)      X    ( 3,16)      X    ( 4,16)      X    ( 5,16)      X    ( 6,16)      X    ( 7,16)
X    38.022  F   X    38.022  F    X    38.161  F    X    38.681  F    X    38.750  F    X    38.812  F    X    38.916  F
X  RHS= 2.659E-04 X  RHS= 2.659E-04 X  RHS= 2.670E-04 X  RHS= 2.726E-04 X  RHS= 2.744E-04 X  RHS= 2.760E-04 X  RHS= 2.779E-04
     10       0.0       1      -0.845       1      -1.100       1       0.109       1       0.766       1       1.263       1       1.494
X  TNU= 1.234E+00 X  TNU= 1.234E+00 X  TNU= 2.072E+00 X  TNU= 1.527E+00 X  TNU= 1.003E+00 X  TNU= 6.509E-01 X  TNU= 3.539E-01
X  TKE= 5.550E-02 X  TKE= 5.550E-02 X  TKE= 1.009E-01 X  TKE= 6.009E-02 X  TKE= 3.812E-02 X  TKE= 2.703E-02 X  TKE= 2.700E-02
X  CHI= 4.051E-03 X  CHI= 4.051E-03 X  CHI= 6.163E-03 X  CHI= 4.561E-03 X  CHI= 3.381E-03 X  CHI= 2.699E-03 X  CHI= 2.159E-03
X  VAP= 2.349E-04 X  VAP= 2.349E-04 X  VAP= 2.444E-04 X  VAP= 2.383E-04 X  VAP= 2.110E-04 X  VAP= 1.866E-04 X  VAP= 1.660E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   9.471 XXXXXXXXX   9.471 XXXXXXXXX   2.067 XXXXXXXXX   0.079 XXXXXXXXX  -2.650 XXXXXXXXX  -3.200 XXXXXXXXX  -2.685 XXXX
X         V20    X          V20    X          V20    X          V20    X                 X                 X
X    ( 1,15)     X    ( 2,15)      X    ( 3,15)      X    ( 4,15)      X    ( 5,15)      X    ( 6,15)      X    ( 7,15)
X    36.941  F   X    36.941  F    X    37.655  F    X    37.884  F    X    38.237  F    X    38.403  F    X    38.500  F
X  RHS= 2.624E-04 X  RHS= 2.624E-04 X  RHS= 2.693E-04 X  RHS= 2.717E-04 X  RHS= 2.765E-04 X  RHS= 2.793E-04 X  RHS= 2.811E-04
     10       0.0       1      -1.452       1      -1.228       1      -0.945       1       0.052       1       0.703       1       1.080
X  TNU= 1.131E+00 X  TNU= 1.131E+00 X  TNU= 1.709E+00 X  TNU= 1.330E+00 X  TNU= 9.687E-01 X  TNU= 5.910E-01 X  TNU= 3.347E-01
X  TKE= 5.084E-02 X  TKE= 5.084E-02 X  TKE= 7.836E-02 X  TKE= 4.551E-02 X  TKE= 3.396E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02
X  CHI= 3.984E-03 X  CHI= 3.984E-03 X  CHI= 6.531E-03 X  CHI= 5.985E-03 X  CHI= 3.791E-03 X  CHI= 2.954E-03 X  CHI= 2.378E-03
X  VAP= 2.328E-04 X  VAP= 2.328E-04 X  VAP= 2.415E-04 X  VAP= 2.431E-04 X  VAP= 2.142E-04 X  VAP= 1.888E-04 X  VAP= 1.697E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   7.932 XXXXXXXXX   7.932 XXXXXXXXX   2.265 XXXXXXXXX   0.341 XXXXXXXXX  -1.671 XXXXXXXXX  -2.564 XXXXXXXXX  -2.322 XXXX
X         V20    X          V20    X          V20    X          V20    X                 X                 X
X    ( 1,14)     X    ( 2,14)      X    ( 3,14)      X    ( 4,14)      X    ( 5,14)      X    ( 6,14)      X    ( 7,14)
X    36.227  F   X    36.227  F    X    37.544  F    X    37.530  F    X    37.939  F    X    38.126  F    X    38.230  F
X  RHS= 2.628E-04 X  RHS= 2.628E-04 X  RHS= 2.762E-04 X  RHS= 2.758E-04 X  RHS= 2.810E-04 X  RHS= 2.842E-04 X  RHS= 2.861E-04
     10       0.0       1      -1.684       1      -1.341       1      -1.108       1      -0.340       1       0.312       1       0.719
X  TNU= 9.517E-01 X  TNU= 9.517E-01 X  TNU= 1.205E+00 X  TNU= 1.038E+00 X  TNU= 9.110E-01 X  TNU= 5.174E-01 X  TNU= 3.880E-01
X  TKE= 4.160E-02 X  TKE= 4.160E-02 X  TKE= 5.000E-02 X  TKE= 3.307E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02
X  CHI= 3.705E-03 X  CHI= 3.705E-03 X  CHI= 6.354E-03 X  CHI= 7.020E-03 X  CHI= 4.566E-03 X  CHI= 3.323E-03 X  CHI= 2.645E-03
X  VAP= 2.300E-04 X  VAP= 2.300E-04 X  VAP= 2.344E-04 X  VAP= 2.418E-04 X  VAP= 2.194E-04 X  VAP= 1.915E-04 X  VAP= 1.729E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   6.173 XXXXXXXXX   6.173 XXXXXXXXX   2.578 XXXXXXXXX   0.550 XXXXXXXXX  -0.924 XXXXXXXXX  -1.931 XXXXXXXXX  -1.933 XXXX
X         V20    X          V20    X                 X          V20    X                 X                 X
X    ( 1,13)     X    ( 2,13)      X    ( 3,13)      X    ( 4,13)      X    ( 5,13)      X    ( 6,13)      X    ( 7,13)
X    35.735  F   X    35.735  F    X    37.558  F    X    37.558  F    X    37.683  F    X    37.856  F    X    37.967  F
X  RHS= 2.654E-04 X  RHS= 2.654E-04 X  RHS= 2.847E-04 X  RHS= 2.844E-04 X  RHS= 2.861E-04 X  RHS= 2.891E-04 X  RHS= 2.912E-04
     10       0.0       1      -1.774       1      -1.634       1      -1.189       1      -0.616       1       0.020       1       0.457
X  TNU= 7.903E-01 X  TNU= 7.903E-01 X  TNU= 8.090E-01 X  TNU= 7.214E-01 X  TNU= 7.580E-01 X  TNU= 4.595E-01 X  TNU= 4.350E-01
X  TKE= 3.447E-02 X  TKE= 3.447E-02 X  TKE= 3.285E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02
X  CHI= 3.267E-03 X  CHI= 3.267E-03 X  CHI= 5.543E-03 X  CHI= 6.717E-03 X  CHI= 5.490E-03 X  CHI= 3.885E-03 X  CHI= 2.967E-03
X  VAP= 2.272E-04 X  VAP= 2.272E-04 X  VAP= 2.250E-04 X  VAP= 2.329E-04 X  VAP= 2.235E-04 X  VAP= 1.965E-04 X  VAP= 1.767E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  5.0330E+02 , CYCLE NUMBER =  154 ,  PRESSURE ITERATION NUMBER =   4 , DT =  3.9186E+00
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XXXXX    4.348 XXXXXXXXX    4.348 XXXXXXXXX    2.690 XXXXXXXXX    0.971 XXXXXXXXX   -0.373 XXXXXXXXX   -1.317 XXXXXXXXX   -1.514 XXXX
X          V20     X          V20     X                 X                 X                 X                 X
X     ( 1,12)      X     ( 2,12)      X     ( 3,12)     X     ( 4,12)     X     ( 5,12)     X     ( 6,12)     X     ( 7,12)
X    35.409   F    X    35.409   F    X    37.336   F   X    37.509   F   X    37.641   F   X    37.759   F   X    37.807   F
X  RHS= 2.697E-04  X  RHS= 2.697E-04  X  RHS= 2.907E-04 X  RHS= 2.923E-04 X  RHS= 2.938E-04 X  RHS= 2.960E-04 X  RHS= 2.974E-04
      10        0.0       1       -1.706     1       -1.803     1       -1.495     1       -0.890     1       -0.268     1         0.274
X  TNU= 6.727E-01  X  TNU= 6.727E-01  X  TNU= 6.089E-01 X  TNU= 5.309E-01 X  TNU= 5.635E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01
X  TKE= 3.094E-02  X  TKE= 3.094E-02  X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02
X  CHI= 2.747E-03  X  CHI= 2.747E-03  X  CHI= 4.554E-03 X  CHI= 5.919E-03 X  CHI= 5.939E-03 X  CHI= 4.426E-03 X  CHI= 3.318E-03
X  VAP= 2.255E-04  X  VAP= 2.255E-04  X  VAP= 2.163E-04 X  VAP= 2.223E-04 X  VAP= 2.217E-04 X  VAP= 2.010E-04 X  VAP= 1.820E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    2.618 XXXXXXXXX    2.618 XXXXXXXXX    2.568 XXXXXXXXX    1.256 XXXXXXXXX    0.211 XXXXXXXXX   -0.713 XXXXXXXXX   -0.988 XXXX
X          V20     X          V20     X                 X                 X                 X                 X
X     ( 1,11)      X     ( 2,11)      X     ( 3,11)     X     ( 4,11)     X     ( 5,11)     X     ( 6,11)     X     ( 7,11)
X    35.201   F    X    35.201   F    X    37.059   F   X    37.281   F   X    37.475   F   X    37.620   F   X    37.683   F
X  RHS= 2.751E-04  X  RHS= 2.751E-04  X  RHS= 2.960E-04 X  RHS= 2.985E-04 X  RHS= 3.007E-04 X  RHS= 3.027E-04 X  RHS= 3.041E-04
      10        0.0       1       -1.505     1       -1.687     1       -1.535     1       -1.114     1       -0.515     1         0.087
X  TNU= 5.935E-01  X  TNU= 5.935E-01  X  TNU= 5.458E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01
X  TKE= 3.050E-02  X  TKE= 3.050E-02  X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02
X  CHI= 2.198E-03  X  CHI= 2.198E-03  X  CHI= 3.455E-03 X  CHI= 4.654E-03 X  CHI= 5.129E-03 X  CHI= 4.482E-03 X  CHI= 3.426E-03
X  VAP= 2.257E-04  X  VAP= 2.257E-04  X  VAP= 2.089E-04 X  VAP= 2.100E-04 X  VAP= 2.104E-04 X  VAP= 2.012E-04 X  VAP= 1.862E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX    1.117 XXXXXXXXX    1.117 XXXXXXXXX    2.370 XXXXXXXXX    1.392 XXXXXXXXX    0.617 XXXXXXXXX   -0.129 XXXXXXXXX   -0.401 XXXX
X          V20     X          V20     X                 X                 X                 X                 X
X     ( 1,10)      X     ( 2,10)      X     ( 3,10)     X     ( 4,10)     X     ( 5,10)     X     ( 6,10)     X     ( 7,10)
X    34.959   F    X    34.959   F    X    36.754   F   X    36.983   F   X    37.135   F   X    37.253   F   X    37.322   F
X  RHS= 2.802E-04  X  RHS= 2.802E-04  X  RHS= 3.011E-04 X  RHS= 3.039E-04 X  RHS= 3.058E-04 X  RHS= 3.073E-04 X  RHS= 3.085E-04
      10        0.0       1       -1.185     1       -1.418     1       -1.396     1       -1.189     1       -0.689     1        -0.221
X  TNU= 5.530E-01  X  TNU= 5.530E-01  X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01
X  TKE= 3.060E-02  X  TKE= 3.060E-02  X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02
X  CHI= 1.706E-03  X  CHI= 1.706E-03  X  CHI= 2.467E-03 X  CHI= 3.205E-03 X  CHI= 3.624E-03 X  CHI= 3.526E-03 X  CHI= 2.754E-03
X  VAP= 2.289E-04  X  VAP= 2.289E-04  X  VAP= 2.050E-04 X  VAP= 1.999E-04 X  VAP= 1.982E-04 X  VAP= 1.943E-04 X  VAP= 1.849E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   -0.041 XXXXXXXXX   -0.041 XXXXXXXXX    2.131 XXXXXXXXX    1.405 XXXXXXXXX    0.815 XXXXXXXXX    0.362 XXXXXXXXX    0.059 XXXX
X          V20     X          V20     X                 X                 X                 X                 X
X     ( 1, 9)      X     ( 2, 9)      X     ( 3, 9)     X     ( 4, 9)     X     ( 5, 9)     X     ( 6, 9)     X     ( 7, 9)
X    34.682   F    X    34.682   F    X    36.414   F   X    36.643   F   X    36.795   F   X    36.913   F   X    36.920   F
X  RHS= 2.848E-04  X  RHS= 2.848E-04  X  RHS= 3.055E-04 X  RHS= 3.086E-04 X  RHS= 3.106E-04 X  RHS= 3.122E-04 X  RHS= 3.125E-04
      10        0.0       1       -0.707     1       -1.055     1       -1.185     1       -1.140     1       -0.960     1        -0.796
X  TNU= 5.650E-01  X  TNU= 5.650E-01  X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01
X  TKE= 3.090E-02  X  TKE= 3.090E-02  X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02
X  CHI= 1.349E-03  X  CHI= 1.349E-03  X  CHI= 1.807E-03 X  CHI= 2.122E-03 X  CHI= 2.288E-03 X  CHI= 2.15?E-03 X  CHI= 1.682E-03
X  VAP= 2.365E-04  X  VAP= 2.365E-04  X  VAP= 2.057E-04 X  VAP= 1.962E-04 X  VAP= 1.917E-04 X  VAP= 1.88 E-04 X  VAP= 1.836E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   -0.698 XXXXXXXXX   -0.698 XXXXXXXXX    1.784 XXXXXXXXX    1.275 XXXXXXXXX    0.857 XXXXXXXXX    0.53? XXXXXXXXX    0.219 XXXX
X          V20     X          V20     X                 X                 X                 X                 X
X     ( 1, 8)      X     ( 2, 8)      X     ( 3, 8)     X     ( 4, 8)     X     ( 5, 8)     X     ( 6, 8)     X     ( 7, 8)
X    34.536   F    X    34.536   F    X    36.144   F   X    36.338   F   X    36.456   F   X    36.491   F   X    36.504   F
X  RHS= 2.908E-04  X  RHS= 2.908E-04  X  RHS= 3.108E-04 X  RHS= 3.136E-04 X  RHS= 3.153E-04 X  RHS= 3.158E-04 X  RHS= 3.160E-04
      10        0.0       1       -0.071     1       -0.628     1       -0.988     1       -1.166     1       -1.257     1        -1.280
X  TNU= 5.400E-01  X  TNU= 5.400E-01  X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01
X  TKE= 3.120E-02  X  TKE= 3.120E-02  X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02
X  CHI= 1.145E-03  X  CHI= 1.145E-03  X  CHI= 1.443E-03 X  CHI= 1.511E-03 X  CHI= 1.508E-03 X  CHI= 1.382E-03 X  CHI= 1.188E-03
X  VAP= 2.474E-04  X  VAP= 2.474E-04  X  VAP= 2.104E-04 X  VAP= 1.984E-04 X  VAP= 1.931E-04 X  VAP= 1.906E-04 X  VAP= 1.89?E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.?
TIME=  5.0330E+02 , CYCLE NUMBER =   154 ,  PRESSURE ITERATION NUMBER =    4 , DT =  3.9186E+00
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XXXXX  -0.706 XXXXXXXXX  -0.706 XXXXXXXXX   1.238 XXXXXXXXX   0.923 XXXXXXXXX   0.684 XXXXXXXXX   0.451 XXXXXXXXX   0.198 XXXX
X          V20     X          V20     X                X                X                X                X
X     ( 1, 7)      X     ( 2, 7)      X     ( 3, 7)    X     ( 4, 7)    X     ( 5, 7)    X     ( 6, 7)    X     ( 7, 7)
X    34.806   F    X    34.806   F    X    35.888   F  X    36.123   F  X    36.234   F  X    36.269   F  X    36.317   F
X  RHS= 3.017E-04 X  RHS= 3.017E-04 X  RHS= 3.159E-04 X  RHS= 3.194E-04 X  RHS= 3.209E-04 X  RHS= 3.214E-04 X  RHS= 3.219E-04
      10        0.0        1        0.493      1       -0.171      1       -0.706      1       -1.073      1       -1.256      1       -1.312
X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01
X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 1.062E-03 X  CHI= 1.062E-03 X  CHI= 1.247E-03 X  CHI= 1.222E-03 X  CHI= 1.183E-03 X  CHI= 1.114E-03 X  CHI= 1.046E-03
X  VAP= 2.550E-04 X  VAP= 2.550E-04 X  VAP= 2.198E-04 X  VAP= 2.055E-04 X  VAP= 2.009E-04 X  VAP= 2.000E-04 X  VAP= 2.005E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -0.143 XXXXXXXXX  -0.143 XXXXXXXXX   0.591 XXXXXXXXX   0.402 XXXXXXXXX   0.331 XXXXXXXXX   0.278 XXXXXXXXX   0.151 XXXX
X          V20     X          V20     X                X                X                X                X
X     ( 1, 6)      X     ( 2, 6)      X     ( 3, 6)    X     ( 4, 6)    X     ( 5, 6)    X     ( 6, 6)    X     ( 7, 6)
X    35.389   F    X    35.389   F    X    35.825   F  X    35.964   F  X    36.019   F  X    36.102   F  X    36.144   F
X  RHS= 3.168E-04 X  RHS= 3.168E-04 X  RHS= 3.235E-04 X  RHS= 3.258E-04 X  RHS= 3.266E-04 X  RHS= 3.277E-04 X  RHS= 3.281E-04
      10        0.0        1        0.721      1        0.101      1       -0.321      1       -0.627      1       -0.871      1       -0.955
X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01
X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02
X  CHI= 1.028E-03 X  CHI= 1.028E-03 X  CHI= 1.149E-03 X  CHI= 1.094E-03 X  CHI= 1.066E-03 X  CHI= 1.035E-03 X  CHI= 1.010E-03
X  VAP= 2.599E-04 X  VAP= 2.599E-04 X  VAP= 2.285E-04 X  VAP= 2.166E-04 X  VAP= 2.130E-04 X  VAP= 2.127E-04 X  VAP= 2.142E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.651 XXXXXXXXX   0.651 XXXXXXXXX  -0.008 XXXXXXXXX  -0.001 XXXXXXXXX   0.042 XXXXXXXXX   0.049 XXXXXXXXX   0.082 XXXX
X                  X                  X                X                X                X                X
X     ( 1, 5)      X     ( 2, 5)      X     ( 3, 5)    X     ( 4, 5)    X     ( 5, 5)    X     ( 6, 5)    X     ( 7, 5)
X    36.047   F    X    36.047   F    X    35.915   F  X    35.998   F  X    35.998   F  X    35.985   F  X    36.033   F
X  RHS= 3.336E-04 X  RHS= 3.336E-04 X  RHS= 3.332E-04 X  RHS= 3.346E-04 X  RHS= 3.347E-04 X  RHS= 3.345E-04 X  RHS= 3.351E-04
      10        0.0        1        0.606      1        0.180      1       -0.200      1       -0.267      1       -0.424      1       -0.553
X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01
X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02
X  CHI= 1.014E-03 X  CHI= 1.014E-03 X  CHI= 1.083E-03 X  CHI= 1.032E-03 X  CHI= 1.020E-03 X  CHI= 1.009E-03 X  CHI= 1.001E-03
X  VAP= 2.632E-04 X  VAP= 2.632E-04 X  VAP= 2.367E-04 X  VAP= 2.301E-04 X  VAP= 2.274E-04 X  VAP= 2.269E-04 X  VAP= 2.286E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   1.329 XXXXXXXXX   1.329 XXXXXXXXX  -0.410 XXXXXXXXX  -0.359 XXXXXXXXX  -0.006 XXXXXXXXX  -0.089 XXXXXXXXX  -0.031 XXXX
X                  X                  X                X                X                X                X
X     ( 1, 4)      X     ( 2, 4)      X     ( 3, 4)    X     ( 4, 4)    X     ( 5, 4)    X     ( 6, 4)    X     ( 7, 4)
X    36.664   F    X    36.664   F    X    36.019   F  X    35.943   F  X    35.998   F  X    35.992   F  X    35.978   F
X  RHS= 3.507E-04 X  RHS= 3.507E-04 X  RHS= 3.431E-04 X  RHS= 3.424E-04 X  RHS= 3.431E-04 X  RHS= 3.431E-04 X  RHS= 3.429E-04
      10        0.0        1        0.088      1        0.612      1        0.231      1        0.104      1        0.061      1       -0.025
X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01
X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02
X  CHI= 1.008E-03 X  CHI= 1.008E-03 X  CHI= 1.037E-03 X  CHI= 1.018E-03 X  CHI= 1.005E-03 X  CHI= 1.002E-03 X  CHI= 9.997E-04
X  VAP= 2.654E-04 X  VAP= 2.654E-04 X  VAP= 2.489E-04 X  VAP= 2.426E-04 X  VAP= 2.421E-04 X  VAP= 2.410E-04 X  VAP= 2.424E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   1.482 XXXXXXXXX   1.482 XXXXXXXXX   0.139 XXXXXXXXX  -0.715 XXXXXXXXX  -0.111 XXXXXXXXX  -0.111 XXXXXXXXX  -0.098 XXXX
X                  X                  X                X                X                X                X
X     ( 1, 3)      X     ( 2, 3)      X     ( 3, 3)    X     ( 4, 3)    X     ( 5, 3)    X     ( 6, 3)    X     ( 7, 3)
X    37.170   F    X    37.170   F    X    36.442   F  X    36.227   F  X    36.234   F  X    36.179   F  X    36.130   F
X  RHS= 3.670E-04 X  RHS= 3.670E-04 X  RHS= 3.576E-04 X  RHS= 3.552E-04 X  RHS= 3.551E-04 X  RHS= 3.543E-04 X  RHS= 3.536E-04
      10        0.0        1       -0.348      1       -0.163      1        0.155      1        0.096      1        0.061      1       -0.003
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02
X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.006E-03 X  CHI= 1.009E-03 X  CHI= 1.002E-03 X  CHI= 1.000E-03 X  CHI= 1.000E-03
X  VAP= 2.680E-04 X  VAP= 2.680E-04 X  VAP= 2.606E-04 X  VAP= 2.517E-04 X  VAP= 2.551E-04 X  VAP= 2.554E-04 X  VAP= 2.562E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  5.0330E+02 , CYCLE NUMBER =  154 ,  PRESSURE ITERATION NUMBER =   4 , DT =  3.9186E+00
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XXXXX   1.185 XXXXXXXXX   1.185 XXXXXXXXX   0.351 XXXXXXXXX  -0.373 XXXXXXXXX  -0.146 XXXXXXXXX  -0.124 XXXXXXXXX  -0.141 XXXX
X                X                X                X                X                X                X
X     ( 1, 2)    X     ( 2, 2)    X     ( 3, 2)    X     ( 4, 2)    X     ( 5, 2)    X     ( 6, 2)    X     ( 7, 2)
X   38.092  F    X   38.092  F    X   37.142  F    X   36.927  F    X   36.747  F    X   36.608  F    X   36.463  F
X  RHS= 3.900E-04 X  RHS= 3.900E-04 X  RHS= 3.766E-04 X  RHS= 3.736E-04 X  RHS= 3.711E-04 X  RHS= 3.691E-04 X  RHS= 3.671E-04
       10       0.0       1      -1.234       1      -1.627       1      -1.299       1      -1.200       1      -1.124       1      -1.033
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03 X  CHI= 1.001E-03
X  VAP= 2.714E-04 X  VAP= 2.714E-04 X  VAP= 2.695E-04 X  VAP= 2.680E-04 X  VAP= 2.693E-04 X  VAP= 2.696E-04 X  VAP= 2.698E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                X                X                X                X                X                X
X     ( 1, 1)    X     ( 2, 1)    X     ( 3, 1)    X     ( 4, 1)    X     ( 5, 1)    X     ( 6, 1)    X     ( 7, 1)
X   38.092  F    X   38.092  F    X   37.142  F    X   36.927  F    X   36.747  F    X   36.608  F    X   36.463  F
X  RHS= 3.900E-04 X  RHS= 3.900E-04 X  RHS= 3.766E-04 X  RHS= 3.736E-04 X  RHS= 3.711E-04 X  RHS= 3.691E-04 X  RHS= 3.671E-04
        2       1.234      10       1.234      10       1.627      10       1.299      10       1.200      10       1.124      10       1.033
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.002E-03 X  CHI= 1.001E-03 X  CHI= 1.001E-03
X  VAP= 2.714E-04 X  VAP= 2.714E-04 X  VAP= 2.695E-04 X  VAP= 2.680E-04 X  VAP= 2.693E-04 X  VAP= 2.696E-04 X  VAP= 2.698E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  L'Q= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  5.0330E+02 , CYCLE NUMBER =   154 ,  PRESSURE ITERATION NUMBER =    4 , DT =  3.9186E+00
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PLUME CENTER AT 1782.27 FEET. PLUME SPEED IS   16.81  DOWNWIND DISTANCE IS 7911.
   TOTAL  ENERGY   ON MESH IS   0.73843E+08
TIME=  5.0330E+02 , CYCLE NUMBER =  154 ,  PRESSURE ITERATION NUMBER =   4 , DT =  3.9186E+00 , MAX DIVERGENCE =  5.2595E-04
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XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                 X                 X                 X                 X                 X                 X
X    ( 1,22)      X    ( 2,22)      X    ( 3,22)      X    ( 4,22)      X    ( 5,22)      X    ( 6,22)      X    ( 7,22)
X   39.145  F     X   39.145  F     X   39.859  F     X   40.399  F     X   40.656  F     X   40.670  F     X   40.635  F
X RHS= 3.608E-04  X RHS= 3.607E-04  X RHS= 3.605E-04  X RHS= 3.608E-04  X RHS= 3.611E-04  X RHS= 3.609E-04  X RHS= 3.625E-04
     2       0.0     10      1.525    10      1.064    10     -0.836    10     -2.389    10     -2.493    10     -2.276
X TNU= 1.722E+00  X TNU= 1.722E+00  X TNU= 7.150E-01  X TNU= 1.152E-01  X TNU= 2.100E-02  X TNU= 2.100E-02  X TNU= 2.100E-02
X TKE= 9.889E-02  X TKE= 9.889E-02  X TKE= 4.028E-02  X TKE= 2.100E-02  X TKE= 2.100E-02  X TKE= 2.100E-02  X TKE= 2.100E-02
X CHI= 0.0        X CHI= 0.0        X CHI= 0.0        X CHI= 0.0        X CHI= 0.0        X CHI= 0.0        X CHI= 0.0
X VAP= 1.947E-04  X VAP= 1.947E-04  X VAP= 1.488E-04  X VAP= 1.175E-04  X VAP= 1.078E-04  X VAP= 1.078E-04  X VAP= 1.082E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X         V20     X         V20     X                 X                 X                 X                 X
X    ( 1,21)      X    ( 2,21)      X    ( 3,21)      X    ( 4,21)      X    ( 5,21)      X    ( 6,21)      X    ( 7,21)
X   39.145  F     X   39.145  F     X   39.859  F     X   40.399  F     X   40.656  F     X   40.670  F     X   40.635  F
X RHS= 2.417E-04  X RHS= 2.417E-04  X RHS= 2.501E-04  X RHS= 2.566E-04  X RHS= 2.595E-04  X RHS= 2.596E-04  X RHS= 2.592E-04
    10       0.0      1      1.525     1      1.064     1     -0.836     1     -2.389     1     -2.493     1     -2.276
X TNU= 1.722E+00  X TNU= 1.722E+00  X TNU= 7.150E-01  X TNU= 1.152E-01  X TNU= 2.100E-02  X TNU= 2.100E-02  X TNU= 2.100E-02
X TKE= 9.889E-02  X TKE= 9.889E-02  X TKE= 4.028E-02  X TKE= 2.100E-02  X TKE= 2.100E-02  X TKE= 2.100E-02  X TKE= 2.100E-02
X CHI= 2.924E-03  X CHI= 2.924E-03  X CHI= 1.830E-03  X CHI= 1.170E-03  X CHI= 9.983E-04  X CHI= 9.982E-04  X CHI= 9.981E-04
X VAP= 1.947E-04  X VAP= 1.947E-04  X VAP= 1.488E-04  X VAP= 1.175E-04  X VAP= 1.078E-04  X VAP= 1.078E-04  X VAP= 1.082E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX   1.615 XXXXXXXXX   1.615 XXXXXXXXX  -0.434 XXXXXXXXX  -1.875 XXXXXXXXX  -1.530 XXXXXXXXX  -0.081 XXXXXXXXX   0.239 XXXX
X         V10     X         V10     X         V20     X                 X                 X                 X
X    ( 1,20)      X    ( 2,20)      X    ( 3,20)      X    ( 4,20)      X    ( 5,20)      X    ( 6,20)      X    ( 7,20)
X   38.528  F     X   38.528  F     X   39.103  F     X   39.693  F     X   39.824  F     X   39.679  F     X   39.859  F
X RHS= 2.415E-04  X RHS= 2.415E-04  X RHS= 2.481E-04  X RHS= 2.553E-04  X RHS= 2.575E-04  X RHS= 2.566E-04  X RHS= 2.587E-04
    10       0.0      1      1.932     1      2.209     1      1.822     1      0.950     1     -0.919     1     -1.765
X TNU= 2.118E+00  X TNU= 2.118E+00  X TNU= 1.762E+00  X TNU= 9.781E-01  X TNU= 5.483E-01  X TNU= 1.943E-01  X TNU= 3.200E-02
X TKE= 1.123E-01  X TKE= 1.123E-01  X TKE= 9.284E-02  X TKE= 5.352E-02  X TKE= 3.266E-02  X TKE= 2.200E-02  X TKE= 2.200E-02
X CHI= 4.111E-03  X CHI= 4.111E-03  X CHI= 3.113E-03  X CHI= 2.120E-03  X CHI= 1.596E-03  X CHI= 1.241E-03  X CHI= 1.002E-03
X VAP= 2.353E-04  X VAP= 2.353E-04  X VAP= 2.042E-04  X VAP= 1.629E-04  X VAP= 1.394E-04  X VAP= 1.253E-04  X VAP= 1.154E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX   3.635 XXXXXXXXX   3.635 XXXXXXXXX  -0.129 XXXXXXXXX  -2.236 XXXXXXXXX  -2.377 XXXXXXXXX  -1.926 XXXXXXXXX  -0.583 XXXX
X         V10     X         V10     X         V10     X                 X                 X                 X
X    ( 1,19)      X    ( 2,19)      X    ( 3,19)      X    ( 4,19)      X    ( 5,19)      X    ( 6,19)      X    ( 7,19)
X   38.563  F     X   38.563  F     X   38.591  F     X   39.131  F     X   39.304  F     X   39.339  F     X   39.304  F
X RHS= 2.489E-04  X RHS= 2.489E-04  X RHS= 2.493E-04  X RHS= 2.558E-04  X RHS= 2.586E-04  X RHS= 2.50[illegible]E-04  X RHS= 2.599E-04
    10       0.0      1      1.101     1      1.918     1      2.059     1      1.647     1      1.040     1      0.201
X TNU= 1.570E+00  X TNU= 1.570E+00  X TNU= 2.120E+00  X TNU= 1.464E+00  X TNU= 9.466E-01  X TNU= 4.599E-01  X TNU= 1.331E-01
X TKE= 6.208E-02  X TKE= 6.208E-02  X TKE= 9.771E-02  X TKE= 6.520E-02  X TKE= 4.700E-02  X TKE= 4.700E-02  X TKE= 4.700E-02
X CHI= 4.368E-03  X CHI= 4.368E-03  X CHI= 4.064E-03  X CHI= 3.001E-03  X CHI= 2.259E-03  X CHI= 1.698E-03  X CHI= 1.413E-03
X VAP= 2.354E-04  X VAP= 2.354E-04  X VAP= 2.329E-04  X VAP= 1.984E-04  X VAP= 1.697E-04  X VAP= 1.469E-04  X VAP= 1.358E-04
X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
XXXXX   4.820 XXXXXXXXX   4.820 XXXXXXXXX   0.717 XXXXXXXXX  -2.069 XXXXXXXXX  -2.763 XXXXXXXXX  -2.509 XXXXXXXXX  -1.399 XXXX
X         V20     X         V20     X         V10     X         V20     X                 X                 X
X    ( 1,18)      X    ( 2,18)      X    ( 3,18)      X    ( 4,18)      X    ( 5,18)      X    ( 6,18)      X    ( 7,18)
X   39.187  F     X   39.187  F     X   38.189  F     X   38.549  F     X   38.798  F     X   38.930  F     X   38.937  F
X RHS= 2.625E-04  X RHS= 2.625E-04  X RHS= 2.524E-04  X RHS= 2.568E-04  X RHS= 2.604E-04  X RHS= 2.626E-04  X RHS= 2.632E-04
    10       0.0      1     -0.123     1      0.785     1      1.243     1      1.329     1      1.218     1      0.842
X TNU= 1.468E+00  X TNU= 1.468E+00  X TNU= 2.277E+00  X TNU= 1.628E+00  X TNU= 1.107E+00  X TNU= 6.451E-01  X TNU= 3.[illegible]-01
X TKE= 5.395E-02  X TKE= 5.395E-02  X TKE= 9.402E-02  X TKE= 6.324E-02  X TKE= 4.341E-02  X TKE= 3.496E-02  X TKE= 2.488E-02
X CHI= 4.560E-03  X CHI= 4.560E-03  X CHI= 5.033E-03  X CHI= 3.622E-03  X CHI= 2.711E-03  X CHI= 2.072E-03  X CHI= 1.727E-03
X VAP= 2.351E-04  X VAP= 2.351E-04  X VAP= 2.404E-04  X VAP= 2.15[illegible]-04  X VAP= 1.875E-04  X VAP= 1.637E-04  X VAP= 1.505E[illegible]
X LIQ= 0[illegible]       X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0        X LIQ= 0.0
TIME=  6.[illegible]5E+02 , CYCLE NUMBER =  177 ,  PRESSURE ITERATION NUMBER =  11 , DT =  4.1291E+0[illegible]
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XXXXX   4.773 XXXXXXXXX   4.773 XXXXXXXXX   1.652 XXXXXXXXX  -1.584 XXXXXXXXX  -2.652 XXXXXXXXX  -2.597 XXXXXXXXX  -1.752 XXXX
X          V20    X          V20    X          V10    X          V20    X                 X                 X
X     ( 1,17)     X     ( 2,17)     X     ( 3,17)     X     ( 4,17)     X     ( 5,17)     X     ( 6,17)     X     ( 7,17)
X    39.554  F    X    39.554  F    X    38.417  F    X    38.653  F    X    38.792  F    X    38.895  F    X    38.895  F
X  RHS= 2.739E-04 X  RHS= 2.739E-04 X  RHS= 2.622E-04 X  RHS= 2.651E-04 X  RHS= 2.675E-04 X  RHS= 2.695E-04 X  RHS= 2.700E-04
     10        0.0        1     -1.130        1     -1.211        1      0.325        1      0.677        1      0.862        1      0.910
X  TNU= 1.564E+00 X  TNU= 1.564E+00 X  TNU= 1.979E+00 X  TNU= 1.842E+00 X  TNU= 1.121E+00 X  TNU= 7.162E-01 X  TNU= 4.008E-01
X  TKE= 6.019E-02 X  TKE= 6.019E-02 X  TKE= 7.333E-02 X  TKE= 7.281E-02 X  TKE= 3.911E-02 X  TKE= 2.964E-02 X  TKE= 2.550E-02
X  CHI= 4.755E-03 X  CHI= 4.755E-03 X  CHI= 5.198E-03 X  CHI= 3.770E-03 X  CHI= 2.903E-03 X  CHI= 2.312E-03 X  CHI= 1.949E-03
X  VAP= 2.351E-04 X  VAP= 2.351E-04 X  VAP= 2.372E-04 X  VAP= 2.240E-04 X  VAP= 1.967E-04 X  VAP= 1.748E-04 X  VAP= 1.605E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   3.707 XXXXXXXXX   3.707 XXXXXXXXX   1.597 XXXXXXXXX  -0.024 XXXXXXXXX  -2.277 XXXXXXXXX  -2.389 XXXXXXXXX  -1.682 XXXX
X          V20    X          V20    X          V20    X          V20    X                 X                 X
X     ( 1,16)     X     ( 2,16)     X     ( 3,16)     X     ( 4,16)     X     ( 5,16)     X     ( 6,16)     X     ( 7,16)
X    39.540  F    X    39.540  F    X    38.584  F    X    38.792  F    X    38.847  F    X    38.902  F    X    38.951  F
X  RHS= 2.818E-04 X  RHS= 2.818E-04 X  RHS= 2.717E-04 X  RHS= 2.741E-04 X  RHS= 2.757E-04 X  RHS= 2.772E-04 X  RHS= 2.783E-04
     10        0.0        1     -1.458        1     -1.435        1     -0.894        1     -0.044        1      0.417        1      0.813
X  TNU= 1.467E+00 X  TNU= 1.467E+00 X  TNU= 1.602E+00 X  TNU= 1.472E+00 X  TNU= 1.102E+00 X  TNU= 6.932E-01 X  TNU= 3.944E-01
X  TKE= 5.689E-02 X  TKE= 5.689E-02 X  TKE= 5.401E-02 X  TKE= 4.694E-02 X  TKE= 3.622E-02 X  TKE= 2.700E-02 X  TKE= 2.700E-02
X  CHI= 4.844E-03 X  CHI= 4.844E-03 X  CHI= 5.433E-03 X  CHI= 4.226E-03 X  CHI= 3.048E-03 X  CHI= 2.458E-03 X  CHI= 2.107E-03
X  VAP= 2.339E-04 X  VAP= 2.339E-04 X  VAP= 2.358E-04 X  VAP= 2.278E-04 X  VAP= 2.026E-04 X  VAP= 1.807E-04 X  VAP= 1.665E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   2.297 XXXXXXXXX   2.297 XXXXXXXXX   1.643 XXXXXXXXX   0.539 XXXXXXXXX  -1.406 XXXXXXXXX  -1.908 XXXXXXXXX  -1.267 XXXX
X          V20    X          V20    X          V20    X                 X                 X                 X
X     ( 1,15)     X     ( 2,15)     X     ( 3,15)     X     ( 4,15)     X     ( 5,15)     X     ( 6,15)     X     ( 7,15)
X    39.103  F    X    39.103  F    X    38.597  F    X    38.736  F    X    38.951  F    X    38.993  F    X    38.993  F
X  RHS= 2.851E-04 X  RHS= 2.851E-04 X  RHS= 2.796E-04 X  RHS= 2.814E-04 X  RHS= 2.845E-04 X  RHS= 2.858E-04 X  RHS= 2.864E-04
     10        0.0        1     -1.453        1     -1.451        1     -1.571        1     -0.626        1      0.098        1      0.691
X  TNU= 1.213E+00 X  TNU= 1.213E+00 X  TNU= 1.141E+00 X  TNU= 1.135E+00 X  TNU= 1.034E+00 X  TNU= 6.330E-01 X  TNU= 3.349E-01
X  TKE= 4.544E-02 X  TKE= 4.544E-02 X  TKE= 3.521E-02 X  TKE= 3.217E-02 X  TKE= 3.337E-02 X  TKE= 2.770E-02 X  TKE= 2.770E-02
X  CHI= 4.850E-03 X  CHI= 4.850E-03 X  CHI= 5.741E-03 X  CHI= 4.734E-03 X  CHI= 3.257E-03 X  CHI= 2.640E-03 X  CHI= 2.264E-03
X  VAP= 2.314E-04 X  VAP= 2.314E-04 X  VAP= 2.320E-04 X  VAP= 2.250E-04 X  VAP= 2.056E-04 X  VAP= 1.850E-04 X  VAP= 1.698E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.875 XXXXXXXXX   0.875 XXXXXXXXX   1.665 XXXXXXXXX   0.436 XXXXXXXXX  -0.443 XXXXXXXXX  -1.167 XXXXXXXXX  -0.658 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1,14)     X     ( 2,14)     X     ( 3,14)     X     ( 4,14)     X     ( 5,14)     X     ( 6,14)     X     ( 7,14)
X    38.362  F    X    38.362  F    X    38.431  F    X    38.473  F    X    38.743  F    X    38.875  F    X    38.895  F
X  RHS= 2.853E-04 X  RHS= 2.853E-04 X  RHS= 2.860E-04 X  RHS= 2.865E-04 X  RHS= 2.902E-04 X  RHS= 2.925E-04 X  RHS= 2.934E-04
     10        0.0        1     -1.488        1     -1.522        1     -1.305        1     -0.752        1     -0.006        1      0.529
X  TNU= 9.746E-01 X  TNU= 9.746E-01 X  TNU= 7.799E-01 X  TNU= 8.810E-01 X  TNU= 8.604E-01 X  TNU= 5.238E-01 X  TNU= 3.880E-01
X  TKE= 3.730E-02 X  TKE= 3.730E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02 X  TKE= 2.930E-02
X  CHI= 4.680E-03 X  CHI= 4.680E-03 X  CHI= 5.693E-03 X  CHI= 5.527E-03 X  CHI= 3.827E-03 X  CHI= 2.944E-03 X  CHI= 2.492E-03
X  VAP= 2.280E-04 X  VAP= 2.280E-04 X  VAP= 2.271E-04 X  VAP= 2.263E-04 X  VAP= 2.094E-04 X  VAP= 1.885E-04 X  VAP= 1.725E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -0.602 XXXXXXXXX  -0.602 XXXXXXXXX   1.644 XXXXXXXXX   0.667 XXXXXXXXX   0.123 XXXXXXXXX  -0.409 XXXXXXXXX  -0.111 XXXX
X                 X                 X                 X                 X                 X                 X
X     ( 1,13)     X     ( 2,13)     X     ( 3,13)     X     ( 4,13)     X     ( 5,13)     X     ( 6,13)     X     ( 7,13)
X    37.482  F    X    37.482  F    X    38.223  F    X    38.265  F    X    38.313  F    X    38.459  F    X    38.459  F
X  RHS= 2.839E-04 X  RHS= 2.839E-04 X  RHS= 2.922E-04 X  RHS= 2.926E-04 X  RHS= 2.935E-04 X  RHS= 2.960E-04 X  RHS= 2.967E-04
     10        0.0        1     -1.421        1     -1.593        1     -1.194        1     -0.663        1      0.024        1      0.458
X  TNU= 7.663E-01 X  TNU= 7.663E-01 X  TNU= 5.414E-01 X  TNU= 5.807E-01 X  TNU= 6.205E-01 X  TNU= 4.350E-01 X  TNU= 4.350E-01
X  TKE= 3.294E-02 X  TKE= 3.294E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02 X  TKE= 3.000E-02
X  CHI= 4.245E-03 X  CHI= 4.245E-03 X  CHI= 5.192E-03 X  CHI= 5.609E-03 X  CHI= 4.791E-03 X  CHI= 3.507E-03 X  CHI= 2.825E-03
X  VAP= 2.235E-04 X  VAP= 2.235E-04 X  VAP= 2.201E-04 X  VAP= 2.217E-04 X  VAP= 2.140E-04 X  VAP= 1.933E-04 X  VAP= 1.759E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  6.0115E+02 , CYCLE NUMBER =  177 ,  PRESSURE ITERATION NUMBER =  11 , DT =  4.1291E+00
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XXXXX  -2.031 XXXXXXXXX  -2.031 XXXXXXXXX   1.480 XXXXXXXXX   1.075 XXXXXXXXX   0.662 XXXXXXXXX   0.286 XXXXXXXXX   0.330 XXXX
X               X               X               X               X               X               X
X     ( 1,12)   X     ( 2,12)   X     ( 3,12)   X     ( 4,12)   X     ( 5,12)   X     ( 6,12)   X     ( 7,12)
X    36.470  F  X    36.470  F  X    37.738  F  X    37.960  F  X    38.078  F  X    38.195  F  X    38.216  F
X  RHS= 2.811E-04 X  RHS= 2.811E-04 X  RHS= 2.953E-04 X  RHS= 2.978E-04 X  RHS= 2.993E-04 X  RHS= 3.011E-04 X  RHS= 3.021E-04
      10      0.0       1    -1.213       1    -1.526       1    -1.314       1    -0.772       1    -0.081       1     0.446
X  TNU= 6.586E-01 X  TNU= 6.586E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01
X  TKE= 3.040E-02 X  TKE= 3.040E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02
X  CHI= 3.714E-03 X  CHI= 3.714E-03 X  CHI= 4.369E-03 X  CHI= 5.007E-03 X  CHI= 4.980E-03 X  CHI= 4.142E-03 X  CHI= 3.192E-03
X  VAP= 2.197E-04 X  VAP= 2.197E-04 X  VAP= 2.122E-04 X  VAP= 2.127E-04 X  VAP= 2.099E-04 X  VAP= 1.983E-04 X  VAP= 1.808E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -3.270 XXXXXXXXX  -3.270 XXXXXXXXX   1.168 XXXXXXXXX   1.288 XXXXXXXXX   1.206 XXXXXXXXX   0.980 XXXXXXXXX   0.860 XXXX
X               X               X               X               X               X               X
X     ( 1,11)   X     ( 2,11)   X     ( 3,11)   X     ( 4,11)   X     ( 5,11)   X     ( 6,11)   X     ( 7,11)
X    35.590  F  X    35.590  F  X    37.121  F  X    37.336  F  X    37.544  F  X    37.683  F  X    37.780  F
X  RHS= 2.796E-04 X  RHS= 2.796E-04 X  RHS= 2.969E-04 X  RHS= 2.994E-04 X  RHS= 3.019E-04 X  RHS= 3.037E-04 X  RHS= 3.053E-04
      10      0.0       1    -0.971       1    -1.269       1    -1.147       1    -0.786       1    -0.236       1     0.330
X  TNU= 6.101E-01 X  TNU= 6.101E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01
X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02
X  CHI= 3.122E-03 X  CHI= 3.122E-03 X  CHI= 3.283E-03 X  CHI= 3.792E-03 X  CHI= 3.992E-03 X  CHI= 3.801E-03 X  CHI= 3.125E-03
X  VAP= 2.169E-04 X  VAP= 2.169E-04 X  VAP= 2.053E-04 X  VAP= 2.026E-04 X  VAP= 2.006E-04 X  VAP= 1.959E-04 X  VAP= 1.854E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  L Q= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -4.281 XXXXXXXXX  -4.281 XXXXXXXX(   0.866 XXXXXXXXX   1.406 XXXXXXXXX   1.565 XXXXXXXXX   1.528 XXXXXXXXX   1.423 XXXX
X               X               X               X               X               X               X
X     ( 1,10)   X     ( 2,10)   X     ( 3,10)   X     ( 4,10)   X     ( 5,10)   X     ( 6,10)   X     ( 7,10)
X    34.799  F  X    34.799  F  X    36.511  F  X    36.740  F  X    36.934  F  X    37.087  F  X    37.163  F
X  RHS= 2.790E-04 X  RHS= 2.790E-04 X  RHS= 2.984E-04 X  RHS= 3.013E-04 X  RHS= 3.036E-04 X  RHS= 3.056E-04 X  RHS= 3.067E-04
      10      0.0       1    -0.741       1    -0.948       1    -0.843       1    -0.624       1    -0.320       1    -0.086
X  TNU= 5.907E-01 X  TNU= 5.907E-01 X  TNU= 5.534E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01
X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02
X  CHI= 2.548E-03 X  CHI= 2.548E-03 X  CHI= 2.283E-03 X  CHI= 2.544E-03 X  CHI= 2.670E-03 X  CHI= 2.568E-03 X  CHI= 2.197E-03
X  VAP= 2.163E-04 X  VAP= 2.163E-04 X  VAP= 2.028E-04 X  VAP= 1.967E-04 X  VAP= 1.935E-04 X  VAP= 1.902E-04 X  VAP= 1.848E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -5.071 XXXXXXXXX  -5.071 XXXXXXXXX   0.648 XXXXXXXXX   1.502 XXXXXXXXX   1.776 XXXXXXXXX   1.824 XXXXXXXXX   1.650 XXXX
X               X               X               X               X               X               X
X     ( 1, 9)   X     ( 2, 9)   X     ( 3, 9)   X     ( 4, 9)   X     ( 5, 9)   X     ( 6, 9)   X     ( 7, 9)
X    34.196  F  X    34.196  F  X    35.915  F  X    36.199  F  X    36.387  F  X    36.553  F  X    36.629  F
X  RHS= 2.802E-04 X  RHS= 2.602E-04 X  RHS= 2.998E-04 X  RHS= 3.034E-04 X  RHS= 3.058E-04 X  RHS= 3.079E-04 X  RHS= 3.089E-04
      10      0.0       1    -0.410       1    -0.587       1    -0.511       1    -0.469       1    -0.524       1    -0.643
X  TNU= 5.766E-01 X  TNU= 5.766E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01
X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02
X  CHI= 2.073E-03 X  CHI= 2.073E-03 X  CHI= 1.652E-03 X  CHI= 1.728E-03 X  CHI= 1.730E-03 X  CHI= 1.591E-03 X  CHI= 1.346E-03
X  VAP= 2.190E-04 X  VAP= 2.190E-04 X  VAP= 2.066E-04 X  VAP= 1.972E-04 X  VAP= 1.927E-04 X  VAP= 1.896E-04 X  VAP= 1.867E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -5.538 XXXXXXXXX  -5.538 XXXXXXXXX   0.457 XXXXXXXXX   1.565 XXXXXXXXX   1.806 XXXXXXXXX   1.758 XXXXXXXXX   1.520 XXXX
X               X               X               X               X               X               X
X     ( 1, 8)   X     ( 2, 8)   X     ( 3, 8)   X     ( 4, 8)   X     ( 5, 8)   X     ( 6, 8)   X     ( 7, 8)
X    33.794  F  X    33.794  F  X    35.472  F  X    35.867  F  X    36.026  F  X    36.116  F  X    36.192  F
X  RHS= 2.835E-04 X  RHS= 2.835E-04 X  RHS= 3.027E-04 X  RHS= 3.079E-04 X  RHS= 3.100E-04 X  RHS= 3.111E-04 X  RHS= 3.121E-04
      10      0.0       1     0.812       1     0.008       1    -0.099       1    -0.294       1    -0.610       1    -0.876
X  TNU= 5.567E-01 X  TNU= 5.567E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01
X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02
X  CHI= 1.706E-03 X  CHI= 1.706E-03 X  CHI= 1.379E-03 X  CHI= 1.341E-03 X  CHI= 1.293E-03 X  CHI= 1.189E-03 X  CHI= 1.084E-03
X  VAP= 2.262E-04 X  VAP= 2.262E-04 X  VAP= 2.175E-04 X  VAP= 2.035E-04 X  VAP= 1.974E-04 X  VAP= 1.954E-04 X  VAP= 1.94[illegible]-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  6.0115E+02 , CYCLE NUMBER =   177 ,  PRESSURE ITERATION NUMBER =  11 , DT =  4.1291E+00
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XXXXX  -4.787 XXXXXXXXX  -4.787 XXXXXXXXX  -0.364 XXXXXXXXX   1.442 XXXXXXXXX   1.596 XXXXXXXXX   1.428 XXXXXXXXX   1.241 XXXX
X          V20     X          V20     X                 X                 X                 X                 X
X     ( 1, 7)      X     ( 2, 7)      X     ( 3, 7)     X     ( 4, 7)     X     ( 5, 7)     X     ( 6, 7)     X     ( 7, 7)
X    33.697  F     X    33.697  F     X    35.090  F    X    35.569  F    X    35.867  F    X    35.964  F    X    36.040  F
X  RHS= 2.899E-04 X  RHS= 2.899E-04 X  RHS= 3.058E-04 X  RHS= 3.122E-04 X  RHS= 3.163E-04 X  RHS= 3.175E-04 X  RHS= 3.184E-04
      10        0.0       1       2.132       1       1.754       1       0.825       1       0.155       1      -0.322       1      -0.646
X  TNU= 5.654E-01 X  TNU= 5.654E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01 X  TNU= 4.860E-01
X  TKE= 3.171E-02 X  TKE= 3.171E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 1.393E-03 X  CHI= 1.393E-03 X  CHI= 1.215E-03 X  CHI= 1.185E-03 X  CHI= 1.134E-03 X  CHI= 1.065E-03 X  CHI= 1.022E-03
X  VAP= 2.369E-04 X  VAP= 2.369E-04 X  VAP= 2.350E-04 X  VAP= 2.171E-04 X  VAP= 2.058E-04 X  VAP= 2.045E-04 X  VAP= 2.053E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -2.716 XXXXXXXXX  -2.716 XXXXXXXXX  -0.761 XXXXXXXXX   0.495 XXXXXXXXX   0.909 XXXXXXXXX   0.933 XXXXXXXXX   0.901 XXXX
X          V20     X          V20     X                 X                 X                 X                 X
X     ( 1, 6)      X     ( 2, 6)      X     ( 3, 6)     X     ( 4, 6)     X     ( 5, 6)     X     ( 6, 6)     X     ( 7, 6)
X    34.397  F     X    34.397  F     X    35.444  F    X    35.520  F    X    35.687  F    X    35.818  F    X    35.915  F
X  RHS= 3.055E-04 X  RHS= 3.055E-04 X  RHS= 3.181E-04 X  RHS= 3.197E-04 X  RHS= 3.224E-04 X  RHS= 3.241E-04 X  RHS= 3.252E-04
      10        0.0       1       3.251       1       3.267       1       2.057       1       0.984       1       0.277       1      -0.118
X  TNU= 5.560E-01 X  TNU= 5.560E-01 X  TNU= 4.302E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01 X  TNU= 4.220E-01
X  TKE= 3.652E-02 X  TKE= 3.652E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02
X  CHI= 1.140E-03 X  CHI= 1.140E-03 X  CHI= 1.106E-03 X  CHI= 1.099E-03 X  CHI= 1.074E-03 X  CHI= 1.032E-03 X  CHI= 1.006E-03
X  VAP= 2.514E-04 X  VAP= 2.514E-04 X  VAP= 2.465E-04 X  VAP= 2.315E-04 X  VAP= 2.173E-04 X  VAP= 2.148E-04 X  VAP= 2.171E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.477 XXXXXXXXX   0.477 XXXXXXXXX  -0.766 XXXXXXXXX  -0.733 XXXXXXXXX  -0.183 XXXXXXXXX   0.208 XXXXXXXXX   0.490 XXXX
X                  X                  X                 X                 X                 X                 X
X     ( 1, 5)      X     ( 2, 5)      X     ( 3, 5)     X     ( 4, 5)     X     ( 5, 5)     X     ( 6, 5)     X     ( 7, 5)
X    36.581  F     X    36.581  F     X    36.414  F    X    35.881  F    X    35.770  F    X    35.756  F    X    35.832  F
X  RHS= 3.403E-04 X  RHS= 3.403E-04 X  RHS= 3.387E-04 X  RHS= 3.327E-04 X  RHS= 3.317E-04 X  RHS= 3.317E-04 X  RHS= 3.325E-04
      10        0.0       1       3.025       1       2.758       1       1.846       1       1.263       1       0.791       1       0.380
X  TNU= 4.371E-01 X  TNU= 4.371E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01 X  TNU= 3.980E-01
X  TKE= 3.345E-02 X  TKE= 3.345E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02 X  TKE= 3.240E-02
X  CHI= 1.011E-03 X  CHI= 1.011E-03 X  CHI= 1.046E-03 X  CHI= 1.051E-03 X  CHI= 1.029E-03 X  CHI= 1.012E-03 X  CHI= 1.002E-03
X  VAP= 2.652E-04 X  VAP= 2.652E-04 X  VAP= 2.534E-04 X  VAP= 2.384E-04 X  VAP= 2.295E-04 X  VAP= 2.272E-04 X  VAP= 2.290E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   3.449 XXXXXXXXX   3.449 XXXXXXXXX  -1.053 XXXXXXXXX  -1.664 XXXXXXXXX  -0.785 XXXXXXXXX  -0.282 XXXXXXXXX   0.061 XXXX
X                  X                  X                 X                 X                 X                 X
X     ( 1, 4)      X     ( 2, 4)      X     ( 3, 4)     X     ( 4, 4)     X     ( 5, 4)     X     ( 6, 4)     X     ( 7, 4)
X    37.606  F     X    37.606  F     X    36.560  F    X    35.950  F    X    35.874  F    X    35.881  F    X    35.888  F
X  RHS= 3.631E-04 X  RHS= 3.631E-04 X  RHS= 3.499E-04 X  RHS= 3.425E-04 X  RHS= 3.416E-04 X  RHS= 3.417E-04 X  RHS= 3.417E-04
      10        0.0       1       1.237       1       1.120       1       0.999       1       1.057       1       1.077       1       0.921
X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01 X  TNU= 4.060E-01
X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02 X  TKE= 3.350E-02
X  CHI= 1.007E-03 X  CHI= 1.007E-03 X  CHI= 1.037E-03 X  CHI= 1.034E-03 X  CHI= 1.014E-03 X  CHI= 1.004E-03 X  CHI= 1.000E-03
X  VAP= 2.678E-04 X  VAP= 2.678E-04 X  VAP= 2.531E-04 X  VAP= 2.424E-04 X  VAP= 2.405E-04 X  VAP= 2.404E-04 X  VAP= 2.419E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   4.638 XXXXXXXXX   4.638 XXXXXXXXX  -1.189 XXXXXXXXX  -1.804 XXXXXXXXX  -0.746 XXXXXXXXX  -0.280 XXXXXXXXX  -0.113 XXXX
X                  X                  X                 X                 X                 X                 X
X     ( 1, 3)      X     ( 2, 3)      X     ( 3, 3)     X     ( 4, 3)     X     ( 5, 3)     X     ( 6, 3)     X     ( 7, 3)
X    38.001  F     X    38.001  F     X    36.491  F    X    36.179  F    X    36.262  F    X    36.241  F    X    36.151  F
X  RHS= 3.786E-04 X  RHS= 3.786E-04 X  RHS= 3.583E-04 X  RHS= 3.547E-04 X  RHS= 3.556E-04 X  RHS= 3.552E-04 X  RHS= 3.539E-04
      10        0.0       1      -1.235       1      -0.582       1       0.094       1       0.542       1       0.674       1       0.666
X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02
X  CHI= 1.007E-03 X  CHI= 1.007E-03 X  CHI= 1.014E-03 X  CHI= 1.018E-03 X  CHI= 1.005E-03 X  CHI= 1.001E-03 X  CHI= 1.000E-03
X  VAP= 2.681E-04 X  VAP= 2.681E-04 X  VAP= 2.579E-04 X  VAP= 2.472E-04 X  VAP= 2.522E-04 X  VAP= 2.541E-04 X  VAP= 2.554E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  6.0115E+02 , CYCLE NUMBER =  177 ,  PRESSURE ITERATION NUMBER =  11 , DT =  4.1291E+00
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XXXXX   3.360 XXXXXXXXX   3.360 XXXXXXXXX  -0.554 XXXXXXXXX  -1.146 XXXXXXXXX  -0.315 XXXXXXXXX  -0.165 XXXXXXXXX  -0.137 XXXX
X                X                X                X                X                X                X
X     ( 1, 2)    X     ( 2, 2)    X     ( 3, 2)    X     ( 4, 2)    X     ( 5, 2)    X     ( 6, 2)    X     ( 7, 2)
X   37.870  F    X   37.870  F    X   37.294  F    X   37.038  F    X   37.218  F    X   37.142  F    X   37.024  F
X  RHS= 3.869E-04 X  RHS= 3.869E-04 X  RHS= 3.789E-04 X  RHS= 3.754E-04 X  RHS= 3.777E-04 X  RHS= 3.766E-04 X  RHS= 3.749E-04
      10       0.0       1      -3.306       1      -2.714       1      -1.528       1      -1.172       1      -0.965       1      -0.785
X  TNU= 4.551E-01 X  TNU= 4.551E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.217E-C2 X  TKE= 4.217E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.006E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.002E-03
X  VAP= 2.692E-04 X  VAP= 2.692E-04 X  VAP= 2.664E-04 X  VAP= 2.635E-04 X  VAP= 2.682E-04 X  VAP= 2.690E-04 X  VAP= 2.693E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                X                X                X                X                X                X
X     ( 1, 1)    X     ( 2, 1)    X     ( 3, 1)    X     ( 4, 1)    X     ( 5, 1)    X     ( 6, 1)    X     ( 7, 1)
X   37.870  F    X   37.870  F    X   37.294  F    X   37.038  F    X   37.218  F    X   37.142  F    X   37.024  F
X  RHS= 3.869E-04 X  RHS= 3.869E-04 X  RHS= 3.789E-04 X  RHS= 3.754E-04 X  RHS= 3.777E-04 X  RHS= 3.766E-04 X  RHS= 3.749E-04
       2       3.306      10       3.306      10       2.714      10       1.528      10       1.172      10       0.965      10       0.785
X  TNU= 4.551E-01 X  TNU= 4.551E-01 X  TNU- 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 4.217E-02 X  TKE= 4.217E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.005E-03 X  CHI= 1.006E-03 X  CHI= 1.003E-03 X  CHI= 1.003E-03 X  CHI= 1.002E-03
X  VAP= 2.692E-04 X  VAP= 2.692E-04 X  VAP= 2.664E-04 X  VAP= 2.635E-04 X  VAP= 2.682E-04 X  VAP= 2.690E-04 X  VAP= 2.693E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  L'Q= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  6.0115E+02 , CYCLE NUMBER =  177    PRESSURE ITERATION NUMBER =  11 , DT =  4.1291E+00
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XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                 X                 X                 X                 X                 X                 X
X    ( 1,22)      X    ( 2,22)      X    ( 3,22)      X    ( 4,22)      X    ( 5,22)      X    ( 6,22)      X    ( 7,22)
X   39.332  F     X   39.332  F     X   40.254  F     X   40.351  F     X   40.503  F     X   40.427  F     X   40.365  F
X  RHS= 3.673E-04 X  RHS= 3.668E-04 X  RHS= 3.663E-04 X  RHS= 3.663E-04 X  RHS= 3.672E-04 X  RHS= 3.671E-04 X  RHS= 3.625E-04
      2      0.0      10      2.577     10      1.216     10     -0.762     10     -1.474     10     -1.506     10     -1.445
X  TNU= 2.412E+00 X  TNU= 2.412E+00 X  TNU= 1.613E+00 X  TNU= 3.158E-01 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 1.090E-01 X  TKE= 1.090E-01 X  TKE= 6.612E-02 X  TKE= 2.211E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0       X  CHI= 0.0
X  VAP= 2.211E-04 X  VAP= 2.211E-04 X  VAP= 1.898E-04 X  VAP= 1.272E-04 X  VAP= 1.081E-04 X  VAP= 1.086E-04 X  VAP= 1.091E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X        V10      X        V10      X                 X                 X                 X                 X
X    ( 1,21)      X    ( 2,21)      X    ( 3,21)      X    ( 4,21)      X    ( 5,21)      X    ( 6,21)      X    ( 7,21)
X   39.332  F     X   39.332  F     X   40.254  F     X   40.351  F     X   40.503  F     X   40.427  F     X   40.365  F
X  RHS= 2.425E-04 X  RHS= 2.425E-04 X  RHS= 2.524E-04 X  RHS= 2.557E-04 X  RHS= 2.580E-04 X  RHS= 2.572E-04 X  RHS= 2.565E-04
     10      0.0      1       2.577     1       1.216     1      -0.762     1      -1.474     1      -1.506     1      -1.445
X  TNU= 2.412E+00 X  TNU= 2.412E+00 X  TNU= 1.613E+00 X  TNU= 3.158E-01 X  TNU= 2.100E-02 X  TNU= 2.100E-02 X  TNU= 2.100E-02
X  TKE= 1.090E-01 X  TKE= 1.090E-01 X  TKE= 6.612E-02 X  TKE= 2.211E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02 X  TKE= 2.100E-02
X  CHI= 3.887E-03 X  CHI= 3.887E-03 X  CHI= 2.914E-03 X  CHI= 1.413E-03 X  CHI= 9.992E-04 X  CHI= 1.000E-03 X  CHI= 9.985E-04
X  VAP= 2.211E-04 X  VAP= 2.211E-04 X  VAP= 1.898E-04 X  VAP= 1.272E-04 X  VAP= 1.081E-04 X  VAP= 1.086E-04 X  VAP= 1.091E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   2.488 XXXXXXXXX   2.488 XXXXXXXXX  -1.385 XXXXXXXXX  -2.001 XXXXXXXXX  -0.734 XXXXXXXXX  -0.053 XXXXXXXXX   0.040 XXXX
X        V10      X        V10      X        V20      X                 X                 X                 X
X    ( 1,20)      X    ( 2,20)      X    ( 3,20)      X    ( 4,20)      X    ( 5,20)      X    ( 6,20)      X    ( 7,20)
X   39.221  F     X   39.221  F     X   39.991  F     X   39.880  F     X   40.011  F     X   39.679  F     X   39.609  F
X  RHS= 2.481E-04 X  RHS= 2.481E-04 X  RHS= 2.563E-04 X  RHS= 2.571E-04 X  RHS= 2.594E-04 X  RHS= 2.567E-04 X  RHS= 2.562E-04
     10      0.0      1       2.280     1       1.813     1       1.031     1       0.213     1      -0.873     1      -1.113
X  TNU= 2.433E+00 X  TNU= 2.433E+00 X  TNU= 1.920E+00 X  TNU= 9.522E-01 X  TNU= 4.785E-01 X  TNU= 1.068E-01 X  TNU= 3.200E-02
X  TKE= 1.050E-01 X  TKE= 1.050E-01 X  TKE= 7.617E-02 X  TKE= 3.833E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02 X  TKE= 2.200E-02
X  CHI= 4.634E-03 X  CHI= 4.634E-03 X  CHI= 3.682E-03 X  CHI= 2.342E-03 X  CHI= 1.642E-03 X  CHI= 1.178E-03 X  CHI= 1.009E-03
X  VAP= 2.352E-04 X  VAP= 2.352E-04 X  VAP= 2.136E-04 X  VAP= 1.655E-04 X  VAP= 1.383E-04 X  VAP= 1.225E-04 X  VAP= 1.166E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   4.681 XXXXXXXXX   4.681 XXXXXXXXX  -1.879 XXXXXXXXX  -2.808 XXXXXXXXX  -1.576 XXXXXXXXX  -1.162 XXXXXXXXX  -0.223 XXXX
X        V10      X        V10      X        V20      X                 X                 X                 X
X    ( 1,19)      X    ( 2,19)      X    ( 3,19)      X    ( 4,19)      X    ( 5,19)      X    ( 6,19)      X    ( 7,19)
X   39.062  F     X   39.062  F     X   39.602  F     X   39.485  F     X   39.644  F     X   39.547  F     X   39.277  F
X  RHS= 2.538E-04 X  RHS= 2.538E-04 X  RHS= 2.595E-04 X  RHS= 2.597E-04 X  RHS= 2.623E-04 X  RHS= 2.621E-04 X  RHS= 2.596E-04
     10      0.0      1       1.203     1       0.931     1       0.936     1       0.612     1       0.341     1      -0.181
X  TNU= 2.079E+00 X  TNU= 2.079E+00 X  TNU= 2.018E+00 X  TNU= 1.232E+00 X  TNU= 7.691E-01 X  TNU= 3.218E-01 X  TNU= 3.232E-02
X  TKE= 7.529E-02 X  TKE= 7.529E-02 X  TKE= 7.408E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02 X  TKE= 4.700E-02
X  CHI= 4.814E-03 X  CHI= 4.814E-03 X  CHI= 4.075E-03 X  CHI= 2.893E-03 X  CHI= 2.192E-03 X  CHI= 1.632E-03 X  CHI= 1.409E-03
X  VAP= 2.343E-04 X  VAP= 2.343E-04 X  VAP= 2.250E-04 X  VAP= 1.874E-04 X  VAP= 1.623E-04 X  VAP= 1.418E-04 X  VAP= 1.349E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   5.805 XXXXXXXXX   5.805 XXXXXXXXX  -2.180 XXXXXXXXX  -2.629 XXXXXXXXX  -1.924 XXXXXXXXX  -1.457 XXXXXXXXX  -0.767 XXXX
X        V10      X        V10      X        V10      X                 X                 X                 X
X    ( 1,18)      X    ( 2,18)      X    ( 3,18)      X    ( 4,18)      X    ( 5,18)      X    ( 6,18)      X    ( 7,18)
X   38.500  F     X   38.500  F     X   38.743  F     X   39.062  F     X   39.207  F     X   39.159  F     X   38.965  F
X  RHS= 2.557E-04 X  RHS= 2.557E-04 X  RHS= 2.581E-04 X  RHS= 2.624E-04 X  RHS= 2.648E-04 X  RHS= 2.652E-04 X  RHS= 2.636E-04
     10      0.0      1      -0.877     1       0.122     1       0.448     1       0.403     1       0.315     1       0.115
X  TNU= 2.008E+00 X  TNU= 2.008E+00 X  TNU= 2.511E+00 X  TNU= 1.457E+00 X  TNU= 9.773E-01 X  TNU= 5.282E-01 X  TNU= 2.382E-01
X  TKE= 7.012E-02 X  TKE= 7.012E-02 X  TKE= 9.392E-02 X  TKE= 4.609E-02 X  TKE= 3.631E-02 X  TKE= 2.797E-02 X  TKE= 2.400E-02
X  CHI= 4.865E-03 X  CHI= 4.865E-03 X  CHI= 4.574E-03 X  CHI= 3.372E-03 X  CHI= 2.598E-03 X  CHI= 1.979E-03 X  CHI= 1.692E-03
X  VAP= 2.330E-04 X  VAP= 2.330E-04 X  VAP= 2.335E-04 X  VAP= 2.030E-04 X  VAP= 1.787E-04 X  VAP= 1.569E-04 X  VAP= 1.475E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  7.0119E+02 , CYCLE NUMBER =  197 ,  PRESSURE ITERATION NUMBER =   7 , DT =  4.4945E+00
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PLUME CENTER AT 1804.70 FEET. PLUME SPEED IS   16.93  DOWNWIND DISTANCE IS 9563.
   TOTAL  ENERGY   ON MESH IS   0.73844E+08
TIME=  6.0115E+02 , CYCLE NUMBER =  177 ,  PRESSURE ITERATION NUMBER =  11 , DT =  4.1291E+00 , MAX DIVERGENCE =  5.4582E-04
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XXXXX   4.863 XXXXXXXXX   4.863 XXXXXXXXX  -1.208 XXXXXXXXX  -2.529 XXXXXXXXX  -1.993 XXXXXXXXX  -1.568 XXXXXXXXX  -0.989 XXXX
X        V20    X         V20     X         V20     X                 X                 X                 X
X     ( 1,17)   X     ( 2,17)     X     ( 3,17)     X     ( 4,17)     X     ( 5,17)     X     ( 6,17)     X     ( 7,17)
X    37.925  F  X    37.925  F    X    38.750  F    X    38.875  F    X    39.048  F    X    39.062  F    X    38.972  F
X RHS= 2.575E-04 X RHS= 2.575E-04 X RHS= 2.658E-04 X RHS= 2.678E-04 X RHS= 2.705E-04 X RHS= 2.715E-04 X RHS= 2.710E-04
     10      0.0       1    -1.914      1    -1.034      1    -0.089      1    -0.042      1    -0.013      1    -0.001
X TNU= 2.054E+00 X TNU= 2.054E+00 X TNU= 2.071E+00 X TNU= 1.739E+00 X TNU= 1.043E+00 X TNU= 6.157E-01 X TNU= 3.158E-01
X TKE= 7.547E-02 X TKE= 7.547E-02 X TKE= 6.670E-02 X TKE= 5.538E-02 X TKE= 3.137E-02 X TKE= 2.550E-02 X TKE= 2.550E-02
X CHI= 4.864E-03 X CHI= 4.864E-03 X CHI= 4.535E-03 X CHI= 3.575E-03 X CHI= 2.764E-03 X CHI= 2.170E-03 X CHI= 1.878E-03
X VAP= 2.311E-04 X VAP= 2.311E-04 X VAP= 2.293E-04 X VAP= 2.126E-04 X VAP= 1.875E-04 X VAP= 1.665E-04 X VAP= 1.565E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   2.906 XXXXXXXXX   2.906 XXXXXXXXX  -0.354 XXXXXXXXX  -1.607 XXXXXXXXX  -1.967 XXXXXXXXX  -1.560 XXXXXXXXX  -0.997 XXXX
X        V20    X         V20     X         V20     X                 X                 X                 X
X     ( 1,16)   X     ( 2,16)     X     ( 3,16)     X     ( 4,16)     X     ( 5,16)     X     ( 6,16)     X     ( 7,16)
X    37.669  F  X    37.669  F    X    38.909  F    X    38.909  F    X    38.951  F    X    38.972  F    X    38.923  F
X RHS= 2.626E-04 X RHS= 2.626E-04 X RHS= 2.755E-04 X RHS= 2.760E-04 X RHS= 2.773E-04 X RHS= 2.782E-04 X RHS= 2.781E-04
     10      0.0       1    -2.178      1    -1.891      1    -1.089      1    -0.637      1    -0.377      1    -0.089
X TNU= 1.853E+00 X TNU= 1.853E+00 X TNU= 1.430E+00 X TNU= 1.452E+00 X TNU= 1.020E+00 X TNU= 6.157E-01 X TNU= 3.110E-01
X TKE= 6.874E-02 X TKE= 6.874E-02 X TKE= 3.722E-02 X TKE= 4.105E-02 X TKE= 2.870E-02 X TKE= 2.700E-02 X TKE= 2.700E-02
X CHI= 4.889E-03 X CHI= 4.889E-03 X CHI= 4.458E-03 X CHI= 3.584E-03 X CHI= 2.810E-03 X CHI= 2.293E-03 X CHI= 2.016E-03
X VAP= 2.290E-04 X VAP= 2.290E-04 X VAP= 2.249E-04 X VAP= 2.132E-04 X VAP= 1.917E-04 X VAP= 1.731E-04 X VAP= 1.627E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   0.711 XXXXXXXXX   0.711 XXXXXXXXX  -0.087 XXXXXXXXX  -0.823 XXXXXXXXX  -1.532 XXXXXXXXX  -1.316 XXXXXXXXX  -0.724 XXXX
X        V20    X         V20     X                 X                 X                 X                 X
X     ( 1,15)   X     ( 2,15)     X     ( 3,15)     X     ( 4,15)     X     ( 5,15)     X     ( 6,15)     X     ( 7,15)
X    37.392  F  X    37.392  F    X    38.771  F    X    38.937  F    X    38.986  F    X    38.986  F    X    38.986  F
X RHS= 2.672E-04 X RHS= 2.672E-04 X RHS= 2.820E-04 X RHS= 2.843E-04 X RHS= 2.854E-04 X RHS= 2.860E-04 X RHS= 2.864E-04
     10      0.0       1    -2.346      1    -2.447      1    -2.096      1    -1.317      1    -0.732      1    -0.141
X TNU= 1.594E+00 X TNU= 1.594E+00 X TNU= 9.875E-01 X TNU= 1.031E+00 X TNU= 9.307E-01 X TNU= 5.622E-01 X TNU= 3.270E-01
X TKE= 6.265E-02 X TKE= 6.265E-02 X TKE= 2.770E-02 X TKE= 2.770E-02 X TKE= 2.810E-02 X TKE= 2.770E-02 X TKE= 2.770E-02
X CHI= 4.946E-03 X CHI= 4.946E-03 X CHI= 4.465E-03 X CHI= 3.535E-03 X CHI= 2.845E-03 X CHI= 2.426E-03 X CHI= 2.180E-03
X VAP= 2.258E-04 X VAP= 2.258E-04 X VAP= 2.186E-04 X VAP= 2.073E-04 X VAP= 1.930E-04 X VAP= 1.780E-04 X VAP= 1.677E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -1.621 XXXXXXXXX  -1.621 XXXXXXXXX  -0.201 XXXXXXXXX  -0.485 XXXXXXXXX  -0.765 XXXXXXXXX  -0.743 XXXXXXXXX  -0.145 XXXX
X        V20    X         V20     X                 X                 X                 X                 X
X     ( 1,14)   X     ( 2,14)     X     ( 3,14)     X     ( 4,14)     X     ( 5,14)     X     ( 6,14)     X     ( 7,14)
X    36.809  F  X    36.809  F    X    38.216  F    X    38.473  F    X    38.667  F    X    38.715  F    X    38.577  F
X RHS= 2.690E-04 X RHS= 2.690E-04 X RHS= 2.841E-04 X RHS= 2.873E-04 X RHS= 2.900E-04 X RHS= 2.910E-04 X RHS= 2.899E-04
     10      0.0       1    -2.025      1    -2.307      1    -2.263      1    -1.761      1    -1.069      1    -0.577
X TNU= 1.241E+00 X TNU= 1.241E+00 X TNU= 7.071E-01 X TNU= 7.245E-01 X TNU= 6.554E-01 X TNU= 4.587E-01 X TNU= 3.880E-01
X TKE= 5.346E-02 X TKE= 5.346E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02 X TKE= 2.930E-02
X CHI= 5.076E-03 X CHI= 5.076E-03 X CHI= 4.862E-03 X CHI= 4.029E-03 X CHI= 3.165E-03 X CHI= 2.702E-03 X CHI= 2.500E-03
X VAP= 2.241E-04 X VAP= 2.241E-04 X VAP= 2.182E-04 X VAP= 2.084E-04 X VAP= 1.952E-04 X VAP= 1.823E-04 X VAP= 1.722E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -3.611 XXXXXXXXX  -3.611 XXXXXXXXX  -0.483 XXXXXXXXX  -0.442 XXXXXXXXX  -0.266 XXXXXXXXX  -0.054 XXXXXXXXX   0.344 XXXX
X        V20    X         V20     X                 X                 X                 X                 X
X     ( 1,13)   X     ( 2,13)     X     ( 3,13)     X     ( 4,13)     X     ( 5,13)     X     ( 6,13)     X     ( 7,13)
X    36.539  F  X    36.539  F    X    37.620  F    X    37.752  F    X    37.828  F    X    37.821  F    X    37.752  F
X RHS= 2.739E-04 X RHS= 2.739E-04 X RHS= 2.857E-04 X RHS= 2.874E-04 X RHS= 2.887E-04 X RHS= 2.891E-04 X RHS= 2.888E-04
     10      0.0       1    -1.672      1    -2.081      1    -2.101      1    -1.870      1    -1.380      1    -0.973
X TNU= 1.039E+00 X TNU= 1.039E+00 X TNU= 4.806E-01 X TNU= 4.628E-01 X TNU= 4.400E-01 X TNU= 4.350E-01 X TNU= 4.350E-01
X TKE= 4.828E-02 X TKE= 4.828E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02 X TKE= 3.000E-02
X CHI= 5.032E-03 X CHI= 5.032E-03 X CHI= 5.022E-03 X CHI= 4.661E-03 X CHI= 4.001E-03 X CHI= 3.344E-03 X CHI= 2.843E-03
X VAP= 2.220E-04 X VAP= 2.220E-04 X VAP= 2.159E-04 X VAP= 2.101E-04 X VAP= 2.003E-04 X VAP= 1.884E-04 X VAP= 1.770E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  7.0119E+02 , CYCLE NUMBER =  197 ,  PRESSURE ITERATION NUMBER =   7 , DT =  4.4945E+00
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XXXXX  -5.234 XXXXXXXXX  -5.234 XXXXXXXXX  -0.885 XXXXXXXXX  -0.456 XXXXXXXXX  -0.030 XXXXXXXXX   0.442 XXXXXXXXX   0.756 XXXX
X                X                X                X                X                X                X
X     ( 1,12)    X     ( 2,12)    X     ( 3,12)    X     ( 4,12)    X     ( 5,12)    X     ( 6,12)    X     ( 7,12)
X    36.373  F   X    36.373  F   X    36.893  F   X    36.955  F   X    36.920  F   X    36.920  F   X    36.969  F
X  RHS= 2.801E-04 X  RHS= 2.801E-04 X  RHS= 2.861E-04 X  RHS= 2.870E-04 X  RHS= 2.869E-04 X  RHS= 2.872E-04 X  RHS= 2.881E-04
      10       0.0        1      -1.479      1      -2.070      1      -2.230      1      -2.047      1      -1.674      1      -1.218
X  TNU= 9.496E-01 X  TNU= 9.496E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01 X  TNU= 4.770E-01
X  TKE= 4.632E-02 X  TKE= 4.632E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02 X  TKE= 3.030E-02
X  CHI= 4.804E-03 X  CHI= 4.804E-03 X  CHI= 4.547E-03 X  CHI= 4.364E-03 X  CHI= 3.902E-03 X  CHI= 3.315E-03 X  CHI= 2.744E-03
X  VAP= 2.190E-04 X  VAP= 2.190E-04 X  VAP= 2.093E-04 X  VAP= 2.045E-04 X  VAP= 1.980E-04 X  VAP= 1.902E-04 X  VAP= 1.818E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -6.654 XXXXXXXXX  -6.654 XXXXXXXXX  -1.464 XXXXXXXXX  -0.604 XXXXXXXXX   0.163 XXXXXXXXX   0.824 XXXXXXXXX   1.220 XXXX
X                X                X                X                X                X                X
X     ( 1,11)    X     ( 2,11)    X     ( 3,11)    X     ( 4,11)    X     ( 5,11)    X     ( 6,11)    X     ( 7,11)
X    36.262  F   X    36.262  F   X    36.213  F   X    36.123  F   X    36.047  F   X    36.054  F   X    36.151  F
X  RHS= 2.869E-04 X  RHS= 2.869E-04 X  RHS= 2.869E-04 X  RHS= 2.861E-04 X  RHS= 2.855E-04 X  RHS= 2.857E-04 X  RHS= 2.870E-04
      10       0.0        1      -1.397      1      -2.066      1      -2.324      1      -2.177      1      -1.820      1      -1.446
X  TNU= 9.243E-01 X  TNU= 9.243E-01 X  TNU= 5.507E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01 X  TNU= 5.150E-01
X  TKE= 4.640E-02 X  TKE= 4.640E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02 X  TKE= 3.050E-02
X  CHI= 4.423E-03 X  CHI= 4.423E-03 X  CHI= 3.583E-03 X  CHI= 3.279E-03 X  CHI= 2.855E-03 X  CHI= 2.453E-03 X  CHI= 2.063E-03
X  VAP= 2.158E-04 X  VAP= 2.158E-04 X  VAP= 2.024E-04 X  VAP= 1.974E-04 X  VAP= 1.932E-04 X  VAP= 1.892E-04 X  VAP= 1.845E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -7.989 XXXXXXXXX  -7.989 XXXXXXXXX  -2.116 XXXXXXXXX  -0.846 XXXXXXXXX   0.325 XXXXXXXXX   1.194 XXXXXXXXX   1.607 XXXX
X                X                X                X                X                X                X
X     ( 1,10)    X     ( 2,10)    X     ( 3,10)    X     ( 4,10)    X     ( 5,10)    X     ( 6,10)    X     ( 7,10)
X    36.179  F   X    36.179  F   X    35.610  F   X    35.451  F   X    35.416  F   X    35.513  F   X    35.631  F
X  RHS= 2.942E-04 X  RHS= 2.942E-04 X  RHS= 2.885E-04 X  RHS= 2.869E-04 X  RHS= 2.866E-04 X  RHS= 2.878E-04 X  RHS= 2.892E-04
      10       0.0        1      -1.459      1      -2.193      1      -2.435      1      -2.252      1      -1.910      1      -1.607
X  TNU= 9.401E-01 X  TNU= 9.401E-01 X  TNU= 6.626E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01 X  TNU= 5.530E-01
X  TKE= 4.877E-02 X  TKE= 4.877E-02 X  TKE= 3.555E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02 X  TKE= 3.060E-02
X  CHI= 3.968E-03 X  CHI= 3.968E-03 X  CHI= 2.597E-03 X  CHI= 2.185E-03 X  CHI= 1.842E-03 X  CHI= 1.601E-03 X  CHI= 1.390E-03
X  VAP= 2.131E-04 X  VAP= 2.131E-04 X  VAP= 1.990E-04 X  VAP= 1.948E-04 X  VAP= 1.927E-04 X  VAP= 1.907E-04 X  VAP= 1.881E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -9.387 XXXXXXXXX  -9.387 XXXXXXXXX  -2.830 XXXXXXXXX  -1.071 XXXXXXXXX   0.525 XXXXXXXXX   1.552 XXXXXXXXX   1.925 XXXX
X                X                X                X                X                X                X
X     ( 1, 9)    X     ( 2, 9)    X     ( 3, 9)    X     ( 4, 9)    X     ( 5, 9)    X     ( 6, 9)    X     ( 7, 9)
X    36.061  F   X    36.061  F   X    35.160  F   X    34.993  F   X    35.021  F   X    35.181  F   X    35.333  F
X  RHS= 3.012E-04 X  RHS= 3.012E-04 X  RHS= 2.915E-04 X  RHS= 2.897E-04 X  RHS= 2.901E-04 X  RHS= 2.919E-04 X  RHS= 2.937E-04
      10       0.0        1      -1.548      1      -2.426      1      -2.469      1      -2.148      1      -1.765      1      -1.478
X  TNU= 9.545E-01 X  TNU= 9.545E-01 X  TNU= 7.231E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01 X  TNU= 5.650E-01
X  TKE= 5.049E-02 X  TKE= 5.049E-02 X  TKE= 3.915E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02 X  TKE= 3.090E-02
X  CHI= 3.543E-03 X  CHI= 3.543E-03 X  CHI= 1.898E-03 X  CHI= 1.531E-03 X  CHI= 1.329E-03 X  CHI= 1.200E-03 X  CHI= 1.098E-03
X  VAP= 2.118E-04 X  VAP= 2.118E-04 X  VAP= 2.007E-04 X  VAP= 1.988E-04 X  VAP= 1.984E-04 X  VAP= 1.969E-04 X  VAP= 1.954E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX -10.878 XXXXXXXXX -10.878 XXXXXXXXX  -3.687 XXXXXXXXX  -1.095 XXXXXXXXX   0.864 XXXXXXXXX   1.952 XXXXXXXXX   2.229 XXXX
X                X                X                X                X                X                X
X     ( 1, 8)    X     ( 2, 8)    X     ( 3, 8)    X     ( 4, 8)    X     ( 5, 8)    X     ( 6, 8)    X     ( 7, 8)
X    35.770  F   X    35.770  F   X    34.654  F   X    34.737  F   X    34.862  F   X    35.118  F   X    35.298  F
X  RHS= 3.063E-04 X  RHS= 3.063E-04 X  RHS= 2.938E-04 X  RHS= 2.947E-04 X  RHS= 2.961E-04 X  RHS= 2.991E-04 X  RHS= 3.012E-04
      10       0.0        1      -0.452      1      -1.712      1      -1.745      1      -1.390      1      -1.064      1      -0.850
X  TNU= 9.128E-01 X  TNU= 9.128E-01 X  TNU= 7.131E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01 X  TNU= 5.400E-01
X  TKE= 4.572E-02 X  TKE= 4.572E-02 X  TKE= 3.716E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02 X  TKE= 3.120E-02
X  CHI= 3.381E-03 X  CHI= 3.381E-03 X  CHI= 1.686E-03 X  CHI= 1.295E-03 X  CHI= 1.199E-03 X  CHI= 1.100E-03 X  CHI= 1.034E-03
X  VAP= 2.124E-04 X  VAP= 2.124E-04 X  VAP= 2.082E-04 X  VAP= 2.091E-04 X  VAP= 2.092E-04 X  VAP= 2.063E-04 X  VAP= 2.046E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  7.0119E+02 , CYCLE NUMBER =   197 ,  PRESSURE ITERATION NUMBER =    7 , DT =  4.4945E+00
```

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XXXXX -11.281 XXXXXXXXX -11.281 XXXXXXXXX  -4.928 XXXXXXXXX  -1.109 XXXXXXXXX   1.236 XXXXXXXXX   2.295 XXXXXXXXX   2.460 XXXX
X              X              X              X              X              X              X
X    ( 1, 7)   X    ( 2, 7)   X    ( 3, 7)   X    ( 4, 7)   X    ( 5, 7)   X    ( 6, 7)   X    ( 7, 7)
X   35.250  F  X   35.250  F  X   33.801  F  X   33.774  F  X   34.425  F  X   35.014  F  X   35.368  F
X  RHS= 3.086E-04 X RHS= 3.086E-04 X RHS= 2.920E-04 X RHS= 2.914E-04 X RHS= 2.987E-04 X RHS= 3.057E-04 X RHS= 3.100E-04
      10        0.0        1      2.006      1      2.307      1      1.681      1      1.033      1      0.644      1      0.378
X  TNU= 9.301E-01 X TNU= 9.301E-01 X TNU= 7.059E-01 X TNU= 5.635E-01 X TNU= 5.138E-01 X TNU= 4.909E-01 X TNU= 4.860E-01
X  TKE= 4.725E-02 X TKE= 4.725E-02 X TKE= 3.323E-02 X TKE= 3.150E-02 X TKE= 3.150E-02 X TKE= 3.150E-02 X TKE= 3.150E-02
X  CHI= 3.266E-03 X CHI= 3.266E-03 X CHI= 2.083E-03 X CHI= 1.643E-03 X CHI= 1.317E-03 X CHI= 1.135E-03 X CHI= 1.040E-03
X  VAP= 2.134E-04 X VAP= 2.134E-04 X VAP= 2.139E-04 X VAP= 2.206E-04 X VAP= 2.226E-04 X VAP= 2.182E-04 X VAP= 2.141E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -9.235 XXXXXXXXX  -9.235 XXXXXXXXX  -4.609 XXXXXXXXX  -1.718 XXXXXXXXX   0.605 XXXXXXXXX   1.923 XXXXXXXXX   2.210 XXXX
X              X              X              X              X              X              X
X    ( 1, 6)   X    ( 2, 6)   X    ( 3, 6)   X    ( 4, 6)   X    ( 5, 6)   X    ( 6, 6)   X    ( 7, 6)
X   34.501  F  X   34.501  F  X   33.087  F  X   32.970  F  X   33.587  F  X   34.474  F  X   35.243  F
X  RHS= 3.083E-04 X RHS= 3.083E-04 X RHS= 2.919E-04 X RHS= 2.904E-04 X RHS= 2.970E-04 X RHS= 3.072E-04 X RHS= 3.166E-04
      10        0.0        1      4.890      1      6.849      1      7.362      1      6.347      1      4.320      1      2.475
X  TNU= 1.323E+00 X TNU= 1.323E+00 X TNU= 1.022E+00 X TNU= 8.456E-01 X TNU= 7.233E-01 X TNU= 5.998E-01 X TNU= 4.649E-01
X  TKE= 1.104E-01 X TKE= 1.104E-01 X TKE= 7.189E-02 X TKE= 5.312E-02 X TKE= 4.219E-02 X TKE= 3.597E-02 X TKE= 3.190E-02
X  CHI= 2.971E-03 X CHI= 2.971E-03 X CHI= 2.282E-03 X CHI= 1.866E-03 X CHI= 1.553E-03 X CHI= 1.289E-03 X CHI= 1.102E-03
X  VAP= 2.156E-04 X VAP= 2.156E-04 X VAP= 2.187E-04 X VAP= 2.251E-04 X VAP= 2.314E-04 X VAP= 2.317E-04 X VAP= 2.251E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -4.317 XXXXXXXXX  -4.317 XXXXXXXXX  -2.634 XXXXXXXXX  -1.190 XXXXXXXXX  -0.394 XXXXXXXXX  -0.090 XXXXXXXXX   0.380 XXXX
X              X              X              X              X              X              X
X    ( 1, 5)   X    ( 2, 5)   X    ( 3, 5)   X    ( 4, 5)   X    ( 5, 5)   X    ( 6, 5)   X    ( 7, 5)
X   38.161  F  X   38.161  F  X   36.899  F  X   36.747  F  X   36.775  F  X   36.449  F  X   36.123  F
X  RHS= 3.621E-04 X RHS= 3.621E-04 X RHS= 3.453E-04 X RHS= 3.431E-04 X RHS= 3.434E-04 X RHS= 3.396E-04 X RHS= 3.359E-04
      10        0.0        1      7.235      1      9.301      1      8.736      1      6.817      1      4.854      1      3.341
X  TNU= 1.539E+00 X TNU= 1.539E+00 X TNU= 1.101E+00 X TNU= [illegible].191E-01 X TNU= 6.478E-01 X TNU= 4.982E-01 X TNU= 4.079E-01
X  TKE= 1.913E-01 X TKE= 1.913E-01 X TKE= 1.051E-01 X TKE= 6.394E-02 X TKE= 4.468E-02 X TKE= 3.390E-02 X TKE= 3.240E-02
X  CHI= 1.756E-03 X CHI= 1.756E-03 X CHI= 1.538E-03 X CHI= 1.315E-03 X CHI= 1.173E-03 X CHI= 1.093E-03 X CHI= 1.041E-03
X  VAP= 2.444E-04 X VAP= 2.444E-04 X VAP= 2.467E-04 X VAP= 2.515E-04 X VAP= 2.522E-04 X VAP= 2.451E-04 X VAP= 2.353E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   2.932 XXXXXXXXX   2.932 XXXXXXXXX  -0.556 XXXXXXXXX  -1.742 XXXXXXXXX  -2.300 XXXXXXXXX  -2.040 XXXXXXXXX  -1.120 XXXX
X              X              X              X              X              X              X
X    ( 1, 4)   X    ( 2, 4)   X    ( 3, 4)   X    ( 4, 4)   X    ( 5, 4)   X    ( 6, 4)   X    ( 7, 4)
X   41.973  F  X   41.973  F  X   39.623  F  X   37.835  F  X   36.789  F  X   36.387  F  X   36.352  F
X  RHS= 4.268E-04 X RHS= 4.268E-04 X RHS= 3.916E-04 X RHS= 3.668E-04 X RHS= 3.532E-04 X RHS= 3.483E-04 X RHS= 3.479E-04
      10        0.0        1      3.480      1      3.838      1      3.040      1      2.540      1      2.629      1      2.751
X  TNU= 6.095E-01 X TNU= 6.095E-01 X TNU= 4.640E-01 X TNU= 4.768E-01 X TNU= 4.522E-01 X TNU= 4.099E-01 X TNU= 4.060E-01
X  TKE= 4.889E-02 X TKE= 4.889E-02 X TKE= 3.392E-02 X TKE= 3.436E-02 X TKE= 3.350E-02 X TKE= 3.350E-02 X TKE= 3.350E-02
X  CHI= 1.022E-03 X CHI= 1.022E-03 X CHI= 1.039E-03 X CHI= 1.069E-03 X CHI= 1.067E-03 X CHI= 1.040E-03 X CHI= 1.017E-03
X  VAP= 2.643E-04 X VAP= 2.643E-04 X VAP= 2.625E-04 X VAP= 2.566E-04 X VAP= 2.482E-04 X VAP= 2.403E-04 X VAP= 2.381E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   6.413 XXXXXXXXX   6.413 XXXXXXXXX  -0.189 XXXXXXXXX  -2.531 XXXXXXXXX  -2.791 XXXXXXXXX  -1.942 XXXXXXXXX  -0.987 XXXX
X              X              X              X              X              X              X
X    ( 1, 3)   X    ( 2, 3)   X    ( 3, 3)   X    ( 4, 3)   X    ( 5, 3)   X    ( 6, 3)   X    ( 7, 3)
X   41.869  F  X   41.869  F  X   37.357  F  X   37.114  F  X   36.775  F  X   36.823  F  X   36.899  F
X  RHS= 4.368E-04 X RHS= 4.368E-04 X RHS= 3.704E-04 X RHS= 3.672E-04 X RHS= 3.628E-04 X RHS= 3.634E-04 X RHS= 3.643E-04
      10        0.0        1     -1.779      1     -1.825      1     -1.031      1      0.388      1      1.522      1      2.054
X  TNU= 5.736E-01 X TNU= 5.736E-01 X TNU= 4.170E-01 X TNU= 4.170E-01 X TNU= 4.175E-01 X TNU= 4.170E-01 X TNU= 4.170E-01
X  TKE= 4.816E-02 X TKE= 4.816E-02 X TKE= 3.610E-02 X TKE= 3.610E-02 X TKE= 3.610E-02 X TKE= 3.610E-02 X TKE= 3.610E-02
X  CHI= 1.024E-03 X CHI= 1.024E-03 X CHI= 1.029E-03 X CHI= 1.041E-03 X CHI= 1.031E-03 X CHI= 1.014E-03 X CHI= 1.006E-03
X  VAP= 2.626E-04 X VAP= 2.626E-04 X VAP= 2.525E-04 X VAP= 2.497E-04 X VAP= 2.456E-04 X VAP= 2.463E-04 X VAP= 2.500E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  7.0119E+02 , CYCLE NUMBER =   197 ,  PRESSURE ITERATION NUMBER =    7 , DT =  4.4945E+00
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XXXXX   4.624 XXXXXXXXX   4.624 XXXXXXXXX  -0.233 XXXXXXXXX  -1.732 XXXXXXXXX  -1.366 XXXXXXXXX  -0.802 XXXXXXXXX  -0.449 XXXX
X                X                X                X                X                X                X
X     ( 1, 2)    X     ( 2, 2)    X     ( 3, 2)    X     ( 4, 2)    X     ( 5, 2)    X     ( 6, 2)    X     ( 7, 2)
X    42.818  F   X    42.818  F   X    40.788  F   X    40.198  F   X    40.732  F   X    41.127  F   X    41.231  F
X  RHS= 4.641E-04 X  RHS= 4.641E-04 X  RHS= 4.313E-04 X  RHS= 4.222E-04 X  RHS= 4.303E-04 X  RHS= 4.363E-04 X  RHS= 4.378E-04
       10       0.0       1      -4.578       1      -4.328       1      -2.581       1      -1.204       1      -0.393       1       0.061
X  TNU= 6.771E-01 X  TNU= 6.771E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 7.125E-02 X  TKE= 7.125E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.022E-03 X  CHI= 1.022E-03 X  CHI= 1.021E-03 X  CHI= 1.023E-03 X  CHI= 1.015E-03 X  CHI= 1.012E-03 X  CHI= 1.011E-03
X  VAP= 2.643E-04 X  VAP= 2.643E-04 X  VAP= 2.608E-04 X  VAP= 2.590E-04 X  VAP= 2.631E-04 X  VAP= 2.669E-04 X  VAP= 2.690E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                X                X                X                X                X                X
X     ( 1, 1)    X     ( 2, 1)    X     ( 3, 1)    X     ( 4, 1)    X     ( 5, 1)    X     ( 6, 1)    X     ( 7, 1)
X    42.818  F   X    42.818  F   X    40.788  F   X    40.198  F   X    40.732  F   X    41.127  F   X    41.231  F
X  RHS= 4.641E-04 X  RHS= 4.641E-04 X  RHS= 4.313E-04 X  RHS= 4.222E-04 X  RHS= 4.303E-04 X  RHS= 4.363E-04 X  RHS= 4.378E-04
        2       4.578    10       4.578    10       4.328    10       2.581    10       1.204    10       0.393    10      -0.061
X  TNU= 6.771E-01 X  TNU= 6.771E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01
X  TKE= 7.125E-02 X  TKE= 7.125E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.022E-03 X  CHI= 1.022E-03 X  CHI= 1.021E-03 X  CHI= 1.023E-03 X  CHI= 1.015E-03 X  CHI= 1.012E-03 X  CHI= 1.011E-03
X  VAP= 2.643E-04 X  VAP= 2.643E-04 X  VAP= 2.608E-04 X  VAP= 2.590E-04 X  VAP= 2.631E-04 X  VAP= 2.669E-04 X  VAP= 2.690E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  L Q= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  7.0119E+02 , CYCLE NUMBER =  197 ,  PRESSURE ITERATION NUMBER =   7 , DT =  4.4945E+00
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PLUME CENTER AT 1789.85 FEET. PLUME SPEED IS   16.74  DOWNWIND DISTANCE IS11251.
   TOTAL  ENERGY   ON MESH IS   0.73844E+08
TIME=  7.0119E+02 , CYCLE NUMBER =  197 ,  PRESSURE ITERATION NUMBER =   7 , DT =  4.4945E+00 , MAX DIVERGENCE =  5.3784E-04
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```
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X               X               X               X               X               X               X
X   ( 1,22)     X   ( 2,22)     X   ( 3,22)     X   ( 4,22)     X   ( 5,22)     X   ( 6,22)     X   ( 7,22)
X  44.239  F    X  44.239  F    X  41.758  F    X  41.737  F    X  41.813  F    X  41.696  F    X  41.592  F
X RHS= 4.203E-04 X RHS= 4.171E-04 X RHS= 4.145E-04 X RHS= 4.123E-04 X RHS= 4.159E-04 X RHS= 4.169E-04 X RHS= 3.625E-04
     2      0.0    10      2.267   10      2.318   10      1.289   10      0.784   10      0.688   10      0.540
X TNU= 3.828E+00 X TNU= 3.828E+00 X TNU= 2.794E+00 X TNU= 1.742E+00 X TNU= 2.360E-01 X TNU= 2.100E-02 X TNU= 2.100E-02
X TKE= 1.797E-01 X TKE= 1.797E-01 X TKE= 1.082E-01 X TKE= 6.706E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02
X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0       X CHI= 0.0
X VAP= 2.332E-04 X VAP= 2.332E-04 X VAP= 2.201E-04 X VAP= 1.817E-04 X VAP= 1.207E-04 X VAP= 1.096E-04 X VAP= 1.094E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X               X               X          V20  X               X               X               X
X   ( 1,21)     X   ( 2,21)     X   ( 3,21)     X   ( 4,21)     X   ( 5,21)     X   ( 6,21)     X   ( 7,21)
X  44.239  F    X  44.239  F    X  41.758  F    X  41.737  F    X  41.813  F    X  41.696  F    X  41.592  F
X RHS= 2.918E-04 X RHS= 2.918E-04 X RHS= 2.662E-04 X RHS= 2.675E-04 X RHS= 2.707E-04 X RHS= 2.699E-04 X RHS= 2.688E-04
    10      0.0     1      2.267    1      2.318    1      1.289    1      0.784    1      0.688    1      0.540
X TNU= 3.828E+00 X TNU= 3.828E+00 X TNU= 2.794E+00 X TNU= 1.742E+00 X TNU= 2.360E-01 X TNU= 2.100E-02 X TNU= 2.100E-02
X TKE= 1.797E-01 X TKE= 1.797E-01 X TKE= 1.082E-01 X TKE= 6.706E-02 X TKE= 2.100E-02 X TKE= 2.100E-02 X TKE= 2.100E-02
X CHI= 4.591E-03 X CHI= 4.591E-03 X CHI= 4.021E-03 X CHI= 2.875E-03 X CHI= 1.304E-03 X CHI= 1.014E-03 X CHI= 1.001E-03
X VAP= 2.332E-04 X VAP= 2.332E-04 X VAP= 2.201E-04 X VAP= 1.817E-04 X VAP= 1.207E-04 X VAP= 1.096E-04 X VAP= 1.094E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   2.318 XXXXXXXXX   2.318 XXXXXXXXX   0.063 XXXXXXXXX  -1.018 XXXXXXXXX  -0.495 XXXXXXXXX  -0.086 XXXXXXXXX  -0.139 XXXX
X               X               X          V20  X               X               X               X
X   ( 1,20)     X   ( 2,20)     X   ( 3,20)     X   ( 4,20)     X   ( 5,20)     X   ( 6,20)     X   ( 7,20)
X  43.796  F    X  43.796  F    X  41.564  F    X  41.626  F    X  41.564  F    X  41.155  F    X  40.898  F
X RHS= 2.953E-04 X RHS= 2.953E-04 X RHS= 2.717E-04 X RHS= 2.739E-04 X RHS= 2.749E-04 X RHS= 2.714E-04 X RHS= 2.692E-04
    10      0.0     1      1.505    1      1.678    1      1.260    1      1.177    1      0.766    1      0.619
X TNU= 2.910E+00 X TNU= 2.910E+00 X TNU= 2.451E+00 X TNU= 1.545E+00 X TNU= 6.292E-01 X TNU= 1.310E-01 X TNU= 3.200E-02
X TKE= 1.075E-01 X TKE= 1.075E-01 X TKE= 8.193E-02 X TKE= 5.099E-02 X TKE= 2.270E-02 X TKE= 2.200E-02 X TKE= 2.200E-02
X CHI= 4.794E-03 X CHI= 4.794E-03 X CHI= 4.308E-03 X CHI= 3.060E-03 X CHI= 1.928E-03 X CHI= 1.316E-03 X CHI= 1.030E-03
X VAP= 2.341E-04 X VAP= 2.341E-04 X VAP= 2.253E-04 X VAP= 1.868E-04 X VAP= 1.470E-04 X VAP= 1.270E-04 X VAP= 1.175E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   3.873 XXXXXXXXX   3.873 XXXXXXXXX   0.251 XXXXXXXXX  -1.424 XXXXXXXXX  -0.566 XXXXXXXXX  -0.486 XXXXXXXXX  -0.275 XXXX
X               X               X          V20  X               X               X               X
X   ( 1,19)     X   ( 2,19)     X   ( 3,19)     X   ( 4,19)     X   ( 5,19)     X   ( 6,19)     X   ( 7,19)
X  43.400  F    X  43.400  F    X  41.411  F    X  41.418  F    X  41.266  F    X  41.002  F    X  40.649  F
X RHS= 2.994E-04 X RHS= 2.994E-04 X RHS= 2.780E-04 X RHS= 2.798E-04 X RHS= 2.792E-04 X RHS= 2.77?E-04 X RHS= 2.736E-04
    10      0.0     1      0.593    1      0.194    1      0.416    1      0.640    1      0.817    1      0.606
X TNU= 2.547E+00 X TNU= 2.547E+00 X TNU= 2.352E+00 X TNU= 1.191E+00 X TNU= 6.000E-01 X TNU= 1.615E-01 X TNU= 2.470E-02
X TKE= 8.407E-02 X TKE= 8.407E-02 X TKE= 7.511E-02 X TKE= 4.700E-02 X TKE= 4.700E-02 X TKE= 4.700E-02 X TKE= 4.700E-02
X CHI= 4.722E-03 X CHI= 4.722E-03 X CHI= 4.246E-03 X CHI= 2.829E-03 X CHI= 2.119E-03 X CHI= 1.595E-03 X CHI= 1.407E-03
X VAP= 2.316E-04 X VAP= 2.316E-04 X VAP= 2.253E-04 X VAP= 1.812E-04 X VAP= 1.574E-04 X VAP= 1.394E-04 X VAP= 1.344E-04
X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX   4.509 XXXXXXXXX   4.509 XXXXXXXXX  -0.132 XXXXXXXXX  -1.187 XXXXXXXXX  -0.329 XXXXXXXXX  -0.298 XXXXXXXXX  -0.474 XXXX
X               X               X               X               X               X               X
X   ( 1,18)     X   ( 2,18)     X   ( 3,18)     X   ( 4,18)     X   ( 5,18)     X   ( 6,18)     X   ( 7,18)
X  42.936  F    X  42.936  F    X  40.822  F    X  41.044  F    X  40.857  F    X  40.628  F    X  40.316  F
X RHS= 3.029E-04 X RHS= 3.029E-04 X RHS= 2.799E-04 X RHS= 2.837E-04 X RHS= 2.824E-04 X RHS= 2.807E-04 X RHS= 2.777E-04
    10      0.0     1     -0.388    1     -0.344    1      0.009    1      0.146    1      0.200    1      0.100
X TNU= 2.503E+00 X TNU= 2.503E+00 X TNU= 2.476E+00 X TNU= 1.179E+00 X TNU= 7.737E-01 X TNU= 3.634E-01 X TNU= 1.[illegible]1
X TKE= 8.427E-02 X TKE= 8.427E-02 X TKE= 8.089E-02 X TKE= 3.563E-02 X TKE= 2.709E-02 X TKE= 2.400E-02 X TKE= 2.400E-02
X CHI= 4.613E-03 X CHI= 4.613E-03 X CHI= 4.129E-03 X CHI= 2.956E-03 X CHI= 2.418E-03 X CHI= 1.882E-03 X CHI= 1.631E-03
X VAP= 2.291E-04 X VAP= 2.291E-04 X VAP= 2.226E-04 X VAP= 1.877E-04 X VAP= 1.708E-04 X VAP= 1.524E-04 X VAP= 1.447E-04
X LIQ= [illegible] X LIQ= 0.0     X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
TIME=  8.[illegible]7E+02 , CYCLE NUMBER =  218 ,  PRESSURE ITERATION NUMBER =   8 , DT =  5.5041E+00
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XXXXX    4.148 XXXXXXXXX    4.148 XXXXXXXXX   -0.072 XXXXXXXXX   -0.820 XXXXXXXXX   -0.180 XXXXXXXXX   -0.233 XXXXXXXXX   -0.564 XXXX
X                  X                  X                  X                  X                  X                  X
X      ( 1,17)     X      ( 2,17)     X      ( 3,17)     X      ( 4,17)     X      ( 5,17)     X      ( 6,17)     X      ( 7,17)
X    42.326   F    X    42.326   F    X    40.351   F    X    40.559   F    X    40.503   F    X    40.379   F    X    40.171   F
X  RHS= 3.046E-04  X  RHS= 3.046E-04  X  RHS= 2.829E-04  X  RHS= 2.861E-04  X  RHS= 2.863E-04  X  RHS= 2.857E-04  X  RHS= 2.838E-04
      10      0.0        1     -0.482        1     -0.311        1     -0.087        1     -0.239        1     -0.379        1     -0.401
X  TNU= 2.243E+00  X  TNU= 2.243E+00  X  TNU= 2.253E+00  X  TNU= 1.358E+00  X  TNU= 8.534E-01  X  TNU= 4.265E-01  X  TNU= 1.800E-01
X  TKE= 7.393E-02  X  TKE= 7.393E-02  X  TKE= 6.645E-02  X  TKE= 3.448E-02  X  TKE= 2.550E-02  X  TKE= 2.550E-02  X  TKE= 2.550E-02
X  CHI= 4.552E-03  X  CHI= 4.552E-03  X  CHI= 4.140E-03  X  CHI= 3.233E-03  X  CHI= 2.594E-03  X  CHI= 2.047E-03  X  CHI= 1.775E-03
X  VAP= 2.265E-04  X  VAP= 2.265E-04  X  VAP= 2.221E-04  X  VAP= 1.993E-04  X  VAP= 1.800E-04  X  VAP= 1.612E-04  X  VAP= 1.522E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX    3.672 XXXXXXXXX    3.672 XXXXXXXXX    0.113 XXXXXXXXX   -0.584 XXXXXXXXX   -0.322 XXXXXXXXX   -0.363 XXXXXXXXX   -0.578 XXXX
X                  X                  X                  X                  X                  X                  X
X      ( 1,16)     X      ( 2,16)     X      ( 3,16)     X      ( 4,16)     X      ( 5,16)     X      ( 6,16)     X      ( 7,16)
X    41.626   F    X    41.626   F    X    40.337   F    X    40.289   F    X    40.254   F    X    40.164   F    X    40.060   F
X  RHS= 3.055E-04  X  RHS= 3.055E-04  X  RHS= 2.912E-04  X  RHS= 2.912E-04  X  RHS= 2.917E-04  X  RHS= 2.914E-04  X  RHS= 2.906E-04
      10      0.0        1     -0.695        1     -0.623        1     -0.373        1     -0.508        1     -0.611        1     -0.504
X  TNU= 1.830E+00  X  TNU= 1.830E+00  X  TNU= 1.432E+00  X  TNU= 1.309E+00  X  TNU= 8.060E-01  X  TNU= 4.237E-01  X  TNU= 2.560E-01
X  TKE= 5.917E-02  X  TKE= 5.917E-02  X  TKE= 3.297E-02  X  TKE= 3.121E-02  X  TKE= 2.700E-02  X  TKE= 2.700E-02  X  TKE= 2.700E-02
X  CHI= 4.455E-03  X  CHI= 4.455E-03  X  CHI= 3.907E-03  X  CHI= 3.280E-03  X  CHI= 2.619E-03  X  CHI= 2.160E-03  X  CHI= 1.938E-03
X  VAP= 2.226E-04  X  VAP= 2.226E-04  X  VAP= 2.161E-04  X  VAP= 2.034E-04  X  VAP= 1.835E-04  X  VAP= 1.674E-04  X  VAP= 1.595E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX    2.958 XXXXXXXXX    2.958 XXXXXXXXX    0.194 XXXXXXXXX   -0.325 XXXXXXXXX   -0.451 XXXXXXXXX   -0.460 XXXXXXXXX   -0.465 XXXX
X                  X                  X                  X                  X                  X                  X
X      ( 1,15)     X      ( 2,15)     X      ( 3,15)     X      ( 4,15)     X      ( 5,15)     X      ( 6,15)     X      ( 7,15)
X    40.580   F    X    40.580   F    X    40.219   F    X    40.198   F    X    40.150   F    X    40.108   F    X    40.032   F
X  RHS= 3.020E-04  X  RHS= 3.020E-04  X  RHS= 2.984E-04  X  RHS= 2.986E-04  X  RHS= 2.986E-04  X  RHS= 2.987E-04  X  RHS= 2.981E-04
      10      0.0        1     -1.113        1     -1.218        1     -0.936        1     -0.762        1     -0.647        1     -0.513
X  TNU= 1.508E+00  X  TNU= 1.508E+00  X  TNU= 9.334E-01  X  TNU= 3.357E-01  X  TNU= 6.990E-01  X  TNU= 4.050E-01  X  TNU= 3.270E-01
X  TKE= 5.319E-02  X  TKE= 5.319E-02  X  TKE= 2.770E-02  X  TKE= 2.770E-02  X  TKE= 2.770E-02  X  TKE= 2.770E-02  X  TKE= 2.770E-02
X  CHI= 4.381E-03  X  CHI= 4.381E-03  X  CHI= 3.665E-03  X  CHI= 3.084E-03  X  CHI= 2.613E-03  X  CHI= 2.288E-03  X  CHI= 2.124E-03
X  VAP= 2.180E-04  X  VAP= 2.180E-04  X  VAP= 2.076E-04  X  VAP= 1.976E-04  X  VAP= 1.844E-04  X  VAP= 1.725E-04  X  VAP= 1.656E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX    1.798 XXXXXXXXX    1.798 XXXXXXXXX    0.092 XXXXXXXXX   -0.042 XXXXXXXXX   -0.275 XXXXXXXXX   -0.345 XXXXXXXXX   -0.330 XXXX
X                  X                  X                  X                  X                  X                  X
X      ( 1,14)     X      ( 2,14)     X      ( 3,14)     X      ( 4,14)     X      ( 5,14)     X      ( 6,14)     X      ( 7,14)
X    39.256   F    X    39.256   F    X    39.679   F    X    39.769   F    X    39.755   F    X    39.616   F    X    39.388   F
X  RHS= 2.955E-04  X  RHS= 2.955E-04  X  RHS= 3.008E-04  X  RHS= 3.023E-04  X  RHS= 3.026E-04  X  RHS= 3.014E-04  X  RHS= 2.991E-04
      10      0.0        1     -0.914        1     -1.203        1     -1.228        1     -1.168        1     -1.233        1     -1.442
X  TNU= 1.138E+00  X  TNU= 1.138E+00  X  TNU= 6.073E-01  X  TNU= 5.584E-01  X  TNU= 4.705E-01  X  TNU= 3.880E-01  X  TNU= 3.880E-01
X  TKE= 4.123E-02  X  TKE= 4.123E-02  X  TKE= 2.930E-02  X  TKE= 2.930E-02  X  TKE= 2.930E-02  X  TKE= 2.930E-02  X  TKE= 2.930E-02
X  CHI= 4.656E-03  X  CHI= 4.656E-03  X  CHI= 4.001E-03  X  CHI= 3.285E-03  X  CHI= 2.797E-03  X  CHI= 2.537E-03  X  CHI= 2.377E-03
X  VAP= 2.182E-04  X  VAP= 2.182E-04  X  VAP= 2.074E-04  X  VAP= 1.962E-04  X  VAP= 1.854E-04  X  VAP= 1.760E-04  X  VAP= 1.692E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
XXXXX    0.812 XXXXXXXXX    0.812 XXXXXXXXX   -0.205 XXXXXXXXX   -0.073 XXXXXXXXX   -0.219 XXXXXXXXX   -0.415 XXXXXXXXX   -0.543 XXXX
X                  X                  X                  X                  X                  X                  X
X      ( 1,13)     X      ( 2,13)     X      ( 3,13)     X      ( 4,13)     X      ( 5,13)     X      ( 6,13)     X      ( 7,13)
X    38.057   F    X    38.057   F    X    38.708   F    X    38.688   F    X    38.591   F    X    38.438   F    X    38.327   F
X  RHS= 2.904E-04  X  RHS= 2.904E-04  X  RHS= 2.981E-04  X  RHS= 2.983E-04  X  RHS= 2.976E-04  X  RHS= 2.963E-04  X  RHS= 2.953E-04
      10      0.0        1     -0.523        1     -0.892        1     -1.342        1     -1.778        1     -2.116        1     -2.277
X  TNU= 9.522E-01  X  TNU= 9.522E-01  X  TNU= 4.350E-01  X  TNU= 4.350E-01  X  TNU= 4.350E-01  X  TNU= 4.350E-01  X  TNU= 4.350E-01
X  TKE= 3.413E-02  X  TKE= 3.413E-02  X  TKE= 3.000E-02  X  TKE= 3.000E-02  X  TKE= 3.000E-02  X  TKE= 3.000E-02  X  TKE= 3.000E-02
X  CHI= 4.872E-03  X  CHI= 4.872E-03  X  CHI= 4.529E-03  X  CHI= 3.926E-03  X  CHI= 3.317E-03  X  CHI= 2.833E-03  X  CHI= 2.466E-03
X  VAP= 2.190E-04  X  VAP= 2.190E-04  X  VAP= 2.097E-04  X  VAP= 1.995E-04  X  VAP= 1.886E-04  X  VAP= 1.795E-04  X  VAP= 1.737E-04
X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0        X  LIQ= 0.0
TIME=  8.0117E+02 , CYCLE NUMBER =  218 ,  PRESSURE ITERATION NUMBER =   8 , DT =  5.5041E+00
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XXXXX   0.205 XXXXXXXXX   0.205 XXXXXXXXX  -0.594 XXXXXXXXX  -0.542 XXXXXXXXX  -0.669 XXXXXXXXX  -0.765 XXXXXXXXX  -0.716 XXXX
X               X               X               X               X               X               X
X     ( 1,12)   X     ( 2,12)   X     ( 3,12)   X     ( 4,12)   X     ( 5,12)   X     ( 6,12)   X     ( 7,12)
X    36.913  F  X    36.913  F  X    37.703  F  X    37.579  F  X    37.419  F  X    37.281  F  X    37.197  F
X  RHS= 2.860E-04 X RHS= 2.860E-04 X RHS= 2.952E-04 X RHS= 2.342E-04 X RHS= 2.927E-04 X RHS= 2.915E-04 X RHS= 2.907E-04
      10       0.0      1      -0.460      1      -1.014      1      -1.724      1      -2.332      1      -2.680      1      -2.764
X  TNU= 8.694E-01 X TNU= 8.694E-01 X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01 X TNU= 4.770E-01
X  TKE= 3.093E-02 X TKE= 3.093E-02 X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02 X TKE= 3.030E-02
X  CHI= 4.845E-03 X CHI= 4.845E-03 X CHI= 4.375E-03 X CHI= 3.767E-03 X CHI= 3.108E-03 X CHI= 2.544E-03 X CHI= 2.111E-03
X  VAP= 2.175E-04 X VAP= 2.175E-04 X VAP= 2.063E-04 X VAP= 1.971E-04 X VAP= 1.886E-04 X VAP= 1.823E-04 X VAP= 1.785E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -0.339 XXXXXXXXX  -0.339 XXXXXXXXX  -1.173 XXXXXXXXX  -1.276 XXXXXXXXX  -1.299 XXXXXXXXX  -1.133 XXXXXXXXX  -0.819 XXXX
X               X               X               X               X               X               X
X     ( 1,11)   X     ( 2,11)   X     ( 3,11)   X     ( 4,11)   X     ( 5,11)   X     ( 6,11)   X     ( 7,11)
X    35.929  F  X    35.929  F  X    36.789  F  X    36.546  F  X    36.352  F  X    36.255  F  X    36.213  F
X  RHS= 2.833E-04 X RHS= 2.833E-04 X RHS= 2.933E-04 X RHS= 2.909E-04 X RHS= 2.890E-04 X RHS= 2.881E-04 X RHS= 2.877E-04
      10       0.0      1      -0.696      1      -1.380      1      -2.155      1      -2.755      1      -3.074      1      -3.110
X  TNU= 8.218E-01 X TNU= 8.218E-01 X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01 X TNU= 5.150E-01
X  TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02 X TKE= 3.050E-02
X  CHI= 4.599E-03 X CHI= 4.599E-03 X CHI= 3.760E-03 X CHI= 3.058E-03 X CHI= 2.396E-03 X CHI= 1.872E-03 X CHI= 1.508E-03
X  VAP= 2.145E-04 X VAP= 2.145E-04 X VAP= 2.015E-04 X VAP= 1.939E-04 X VAP= 1.883E-04 X VAP= 1.848E-04 X VAP= 1.832E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -1.111 XXXXXXXXX  -1.111 XXXXXXXXX  -1.885 XXXXXXXXX  -2.076 XXXXXXXXX  -1.922 XXXXXXXXX  -1.475 XXXXXXXXX  -0.876 XXXX
X               X               X               X               X               X               X
X     ( 1,10)   X     ( 2,10)   X     ( 3,10)   X     ( 4,10)   X     ( 5,10)   X     ( 6,10)   X     ( 7,10)
X    35.063  F  X    35.063  F  X    36.054  F  X    35.763  F  X    35.583  F  X    35.479  F  X    35.458  F
X  RHS= 2.820E-04 X RHS= 2.820E-04 X RHS= 2.935E-04 X RHS= 2.904E-04 X RHS= 2.885E-04 X RHS= 2.874E-04 X RHS= 2.872E-04
      10       0.0      1      -1.005      1      -1.779      1      -2.532      1      -3.086      1      -3.372      1      -3.366
X  TNU= 8.111E-01 X TNU= 8.111E-01 X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01 X TNU= 5.530E-01
X  TKE= 3.074E-02 X TKE= 3.074E-02 X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02 X TKE= 3.060E-02
X  CHI= 4.199E-03 X CHI= 4.199E-03 X CHI= 3.042E-03 X CHI= 2.320E-03 X CHI= 1.734E-03 X CHI= 1.345E-03 X CHI= 1.137E-03
X  VAP= 2.111E-04 X VAP= 2.111E-04 X VAP= 1.983E-04 X VAP= 1.930E-04 X VAP= 1.905E-04 X VAP= 1.900E-04 X VAP= 1.908E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -2.176 XXXXXXXXX  -2.176 XXXXXXXXX  -2.686 XXXXXXXXX  -2.854 XXXXXXXXX  -2.499 XXXXXXXXX  -1.784 XXXXXXXXX  -0.891 XXXX
X               X               X               X               X               X               X
X     ( 1, 9)   X     ( 2, 9)   X     ( 3, 9)   X     ( 4, 9)   X     ( 5, 9)   X     ( 6, 9)   X     ( 7, 9)
X    34.411  F  X    34.411  F  X    35.402  F  X    35.181  F  X    35.042  F  X    34.987  F  X    34.987  F
X  RHS= 2.830E-04 X RHS= 2.830E-04 X RHS= 2.943E-04 X RHS= 2.920E-04 X RHS= 2.904E-04 X RHS= 2.897E-04 X RHS= 2.896E-04
      10       0.0      1      -1.091      1      -1.877      1      -2.596      1      -3.148      1      -3.439      1      -3.404
X  TNU= 8.170E-01 X TNU= 8.170E-01 X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01 X TNU= 5.650E-01
X  TKE= 3.164E-02 X TKE= 3.164E-02 X TKE= 3.090E-02 X TKE= 3.090E-02 X TKE= 3.090E-02 X TKE= 3.09[illegible]E-02 X TKE= 3.090E-02
X  CHI= 3.799E-03 X CHI= 3.799E-03 X CHI= 2.456E-03 X CHI= 1.797E-03 X CHI= 1.350E-03 X CHI= 1.12[illegible]E-03 X CHI= 1.034E-03
X  VAP= 2.088E-04 X VAP= 2.088E-04 X VAP= 1.978E-04 X VAP= 1.954E-04 X VAP= 1.962E-04 X VAP= 1.9[illegible]-04 X VAP= 2.014E-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0
XXXXX  -3.306 XXXXXXXXX  -3.306 XXXXXXXXX  -3.498 XXXXXXXXX  -3.596 XXXXXXXXX  -3.074 XXXXXXXXX  -2.095 XXXXXXXXX  -0.876 XXXX
X               X               X               X               X               X               X
X     ( 1, 8)   X     ( 2, 8)   X     ( 3, 8)   X     ( 4, 8)   X     ( 5, 8)   X     ( 6, 8)   X     ( 7, 8)
X    34.002  F  X    34.002  F  X    34.841  F  X    34.661  F  X    34.578  F  X    34.564  F  X    34.612  F
X  RHS= 2.865E-04 X RHS= 2.865E-04 X RHS= 2.962E-04 X RHS= 2.942E-04 X RHS= 2.931E-04 X RHS= 2.927E-04 X RHS= 2.931E-04
      10       0.0      1      -0.788      1      -1.330      1      -1.934      1      -2.490      1      -2.851      1      -2.869
X  TNU= 8.148E-01 X TNU= 8.148E-01 X TNU= 5.653E-01 X TNU= 5.400E-01 X TNU= 5.400E-01 X TNU= 5.400E-01 X TNU= 5.400E-01
X  TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02 X TKE= 3.120E-02
X  CHI= 3.559E-03 X CHI= 3.559E-03 X CHI= 2.091E-03 X CHI= 1.518E-03 X CHI= 1.202E-03 X CHI= 1.081E-03 X CHI= 1.049E-03
X  VAP= 2.084E-04 X VAP= 2.084E-04 X VAP= 1.996E-04 X VAP= 2.002E-04 X VAP= 2.038E-04 X VAP= 2.084E-04 X VAP= 2.12[illegible]-04
X  LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.0       X LIQ= 0.[illegible]
TIME=  8.0117E+02 , CYCLE NUMBER =  218 ,  PRESSURE ITERATION NUMBER =   8 , DT =  5.5041E+00
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XXXXX  -4.108 XXXXXXXXX  -4.108 XXXXXXXXX  -4.058 XXXXXXXXX  -4.219 XXXXXXXXX  -3.647 XXXXXXXXX  -2.473 XXXXXXXXX  -0.911 XXXX
X                X                X                X                X                X                X
X     ( 1, 7)    X     ( 2, 7)    X     ( 3, 7)    X     ( 4, 7)    X     ( 5, 7)    X     ( 6, 7)    X     ( 7, 7)
X    33.774  F   X    33.774  F   X    34.432  F   X    34.196  F   X    34.016  F   X    33.919  F   X    33.947  F
X  RHS= 2.919E-04 X  RHS= 2.919E-04 X  RHS= 2.997E-04 X  RHS= 2.969E-04 X  RHS= 2.940E-04 X  RHS= 2.932E-04 X  RHS= 2.933E-04
     10        0.0      1       -0.059      1        0.106      1        0.089      1       -0.194      1       -0.713      1       -0.928
X  TNU= 8.277E-01 X  TNU= 8.277E-01 X  TNU= 5.997E-01 X  TNU= 5.242E-01 X  TNU= 5.031E-01 X  TNU= 4.903E-01 X  TNU= 4.944E-01
X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02 X  TKE= 3.150E-02
X  CHI= 3.554E-03 X  CHI= 3.554E-03 X  CHI= 2.049E-03 X  CHI= 1.516E-03 X  CHI= 1.275E-03 X  CHI= 1.192E-03 X  CHI= 1.197E-03
X  VAP= 2.092E-04 X  VAP= 2.092E-04 X  VAP= 2.020E-04 X  VAP= 2.039E-04 X  VAP= 2.102E 04 X  VAP= 2.175E-04 X  VAP= 2.216E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -4.158 XXXXXXXXX  -4.158 XXXXXXXXX  -3.902 XXXXXXXXX  -4.248 XXXXXXXXX  -3.942 XXXXXXXXX  -3.003 XXXXXXXXX  -1.138 XXXX
X                X                X                X                X                X                X
X     ( 1, 6)    X     ( 2, 6)    X     ( 3, 6)    X     ( 4, 6)    X     ( 5, 6)    X     ( 6, 6)    X     ( 7, 6)
X    33.524  F   X    33.524  F   X    33.954  F   X    33.801  F   X    33.531  F   X    33.261  F   X    32.997  F
X  RHS= 2.972E-04 X  RHS= 2.972E-04 X  RHS= 3.023E-04 X  RHS= 3.005E-04 X  RHS= 2.972E-04 X  RHS= 2.939E-04 X  RHS= 2.908E-04
     10        0.0      1        1.151      1        2.054      1        2.608      1        3.063      1        3.427      1        3.352
X  TNU= 9.922E-01 X  TNU= 9.922E-01 X  TNU= 8.018E-01 X  TNU= 6.811E-01 X  TNU= 6.323E-01 X  TNU= 6.437E-01 X  TNU= 7.110E-01
X  TKE= 4.128E-02 X  TKE= 4.128E-02 X  TKE= 3.683E-02 X  TKE= 3.346E-02 X  TKE= 3.190E-02 X  TKE= 3.190E-02 X  TKE= 3.202E-02
X  CHI= 3.501E-03 X  CHI= 3.501E-03 X  CHI= 2.422E-03 X  CHI= 1.890E-03 X  CHI= 1.655E-03 X  CHI= 1.594E-03 X  CHI= 1.626E-03
X  VAP= 2.099E-04 X  VAP= 2.099E-04 X  VAP= 2.059E-04 X  VAP= 2.073E-04 X  VAP= 2.122E-04 X  VAP= 2.177E-04 X  VAP= 2.226E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX  -2.977 XXXXXXXXX  -2.977 XXXXXXXXX  -3.001 XXXXXXXXX  -3.636 XXXXXXXXX  -3.551 XXXXXXXXX  -2.643 XXXXXXXXX  -1.217 XXXX
X                X                X                X                X                X                X
X     ( 1, 5)    X     ( 2, 5)    X     ( 3, 5)    X     ( 4, 5)    X     ( 5, 5)    X     ( 6, 5)    X     ( 7, 5)
X    33.815  F   X    33.815  F   X    33.690  F   X    33.739  F   X    33.545  F   X    33.434  F   X    33.349  F
X  RHS= 3.084E-04 X  RHS= 3.084E-04 X  RHS= 3.072E-04 X  RHS= 3.078E-04 X  RHS= 3.054E-04 X  RHS= 3.039E 04 X  RHS= 3.032E-04
     10        0.0      1        3.081      1        4.451      1        5.336      1        6.120      1        6.282      1        7.366
X  TNU= 1.644E+00 X  TNU= 1.644E+00 X  TNU= 1.330E+00 X  TNU= 1.099E 00 X  TNU= 9.618E-01 X  TNU= 9.129E-01 X  TNU= 3.911E-01
X  TKE= 1.306E-01 X  TKE= 1.306E-01 X  TKE= 8.998E-02 X  TKE= 6.578E-02 X  TKE= 5.282E-02 X  TKE= 4.679E-02 X  TKE= 4.327E-02
X  CHI= 2.895E-03 X  CHI= 2.895E-03 X  CHI= 2.634E-03 X  CHI= 2.331E-03 X  CHI= 2.106E-03 X  CHI= 1.960E-03 X  CHI= 1.672E-03
X  VAP= 2.210E-04 X  VAP= 2.210E-04 X  VAP= 2.158E-04 X  VAP= 2.146E-04 X  VAP= 2.171E-04 X  VAP= 2.217E-04 X  VAP= 2.279E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.152 XXXXXXXXX   0.152 XXXXXXXXX  -1.647 XXXXXXXXX  -2.728 XXXXXXXXX  -2.763 XXXXXXXXX  -1.360 XXXXXXXXX  -0.731 XXXX
X                X                X                X                X                X                X
X     ( 1, 4)    X     ( 2, 4)    X     ( 3, 4)    X     ( 4, 4)    X     ( 5, 4)    X     ( 6, 4)    X     ( 7, 4)
X    36.733  F   X    36.733  F   X    36.179  F   X    35.770  F   X    35.423  F   X    35.340  F   X    35.389  F
X  RHS= 3.519E-04 X  RHS= 3.519E-04 X  RHS= 3.453E-04 X  RHS= 3.403E-04 X  RHS= 3.360E-04 X  RHS= 3.348E-04 X  RHS= 3.352E-04
     10        0.0      1        2.455      1        4.400      1        5.465      1        6.010      1        5.915      1        5.109
X  TNU= 7.203E-01 X  TNU= 7.203E-01 X  TNU= 9.305E-01 X  TNU= 9.465E-01 X  TNU= 9.133E-01 X  TNU= 8.723E-01 X  TNU= 7.394E-01
X  TKE= 5.138E-02 X  TKE= 5.138E-02 X  TKE= 6.200E-02 X  TKE= 5.722E-02 X  TKE= 5.181E-02 X  TKE= 4.297E-02 X  TKE= 4.324E-02
X  CHI= 1.022E-03 X  CHI= 1.022E-03 X  CHI= 1.494E-03 X  CHI= 1.582E-03 X  CHI= 1.673E-03 X  CHI= 1.536E-03 X  CHI= 1.378E-03
X  VAP= 2.582E-04 X  VAP= 2.582E-04 X  VAP= 2.455E-04 X  VAP= 2.397E-04 X  VAP= 2.386E-04 X  VAP= 2.41?E-04 X  VAP= 2.?43E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   2.669 XXXXXXXXX   2.669 XXXXXXXXX   0.307 XXXXXXXXX  -1.054 XXXXXXXXX  -2.209 XXXXXXXXX  -1.967 XXXXXXXXX  -1.529 XXXX
X                X                X                X                X                X                X
X     ( 1, 3)    X     ( 2, 3)    X     ( 3, 3)    X     ( 4, 3)    X     ( 5, 3)    X     ( 6, 3)    X     ( 7, 3)
X    36.470  F   X    36.470  F   X    36.116  F   X    36.109  F   X    35.652  F   X    35.434  F   X    35.333  F
X  RHS= 3.581E-04 X  RHS= 3.581E-04 X  RHS= 3.537E-04 X  RHS= 3.537E-04 X  RHS= 3.478E-04 X  RHS= 3.451E-04 X  RHS= 3.437E-04
     10        0.0      1       -0.561      1       -0.100      1        1.107      1        1.749      1        2.367      1        2.350
X  TNU= 5.324E-01 X  TNU= 5.324E-01 X  TNU= 4.170E-01 X  TNU= 6.109E-01 X  TNU= 6.789E-01 X  TNU= 6.094E-01 X  TNU= 4.350E-01
X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.610E-02 X  TKE= 3.797E-02 X  TKE= 3.919E-02 X  TKE= 3.855E-02 X  TKE= 3.610E-02
X  CHI= 1.019E-03 X  CHI= 1.019E-03 X  CHI= 1.044E-03 X  CHI= 1.227E-03 X  CHI= 1.257E-03 X  CHI= 1.198E-03 X  CHI= 1.116E-03
X  VAP= 2.572E-04 X  VAP= 2.572E-04 X  VAP= 2.523E-04 X  VAP= 2.497E-04 X  VAP= 2.475E-04 X  VAP= 2.464E-04 X  VAP= 2.454E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  8.0117E+02 , CYCLE NUMBER =   218 ,  PRESSURE ITERATION NUMBER =   3 , DT =  5.0041E+00
```

```
XXXXX   2.180 XXXXXXXXX   2.180 XXXXXXXXX   0.787 XXXXXXXXX  -0.434 XXXXXXXXX  -1.554 XXXXXXXXX  -1.637 XXXXXXXXX  -1.234 XXXX
X                X                X                X                X                X                X
X     ( 1, 2)    X     ( 2, 2)    X     ( 3, 2)    X     ( 4, 2)    X     ( 5, 2)    X     ( 6, 2)    X     ( 7, 2)
X    37.163  F   X    37.163  F   X    36.643  F   X    36.387  F   X    36.130  F   X    36.040  F   X    36.338  F
X  RHS= 3.775E-04 X  RHS= 3.775E-04 X  RHS= 3.703E-04 X  RHS= 3.668E-04 X  RHS= 3.634E-04 X  RHS= 3.622E-04 X  RHS= 3.660E-04
       10       0.0       1      -2.310      1      -3.171      1      -2.808      1      -1.319      1       0.257      1       1.432
X  TNU= 5.942E-01 X  TNU= 5.942E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.339E-01 X  TNU= 4.240E-01 X  TNU= 4.170E-01
X  TKE= 5.011E-02 X  TKE= 5.011E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.019E-03 X  CHI= 1.019E-03 X  CHI= 1.027E-03 X  CHI= 1.044E-03 X  CHI= 1.066E-03 X  CHI= 1.048E-03 X  CHI= 1.020E-03
X  VAP= 2.579E-04 X  VAP= 2.579E-04 X  VAP= 2.565E-04 X  VAP= 2.554E-04 X  VAP= 2.542E-04 X  VAP= 2.544E-04 X  VAP= 2.581E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
XXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXXXXXXX   0.0   XXXX
X                X                X                X                X                X                X
X     ( 1, 1)    X     ( 2, 1)    X     ( 3, 1)    X     ( 4, 1)    X     ( 5, 1)    X     ( 6, 1)    X     ( 7, 1)
X    37.163  F   X    37.163  F   X    36.643  F   X    36.387  F   X    36.130  F   X    36.040  F   X    36.338  F
X  RHS= 3.775E-04 X  RHS= 3.775E-04 X  RHS= 3.703E-04 X  RHS= 3.668E-04 X  RHS= 3.634E-04 X  RHS= 3.622E-04 X  RHS= 3.660E-04
        2       2.310     10       2.310     10       3.171     10       2.808     10       1.319     10      -0.257     10      -1.432
X  TNU= 5.942E-01 X  TNU= 5.942E-01 X  TNU= 4.170E-01 X  TNU= 4.170E-01 X  TNU= 4.339E-01 X  TNU= 4.240E-01 X  TNU= 4.170E-01
X  TKE= 5.011E-02 X  TKE= 5.011E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02 X  TKE= 4.080E-02
X  CHI= 1.019E-03 X  CHI= 1.019E-03 X  CHI= 1.027E-03 X  CHI= 1.044E-03 X  CHI= 1.066E-03 X  CHI= 1.048E-03 X  CHI= 1.020E-03
X  VAP= 2.579E-04 X  VAP= 2.579E-04 X  VAP= 2.565E-04 X  VAP= 2.554E-04 X  VAP= 2.542E-04 X  VAP= 2.544E-04 X  VAP= 2.581E-04
X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0       X  LIQ= 0.0
TIME=  8.0117E+02 , CYCLE NUMBER =  218 ,  PRESSURE ITERATION NUMBER =   8 , DT =  5.5041E+00
```

```
PLUME CENTER AT 1764.29 FEET. PLUME SPEED IS   16.45  DOWNWIND DISTANCE IS12908.
   TOTAL  ENERGY   ON MESH IS   0.73843E+08
TIME=  8.0117E+02 , CYCLE NUMBER =  218 ,  PRESSURE ITERATION NUMBER =   8 , DT =  5.5041E+00 , MAX DIVERGENCE =  7.8915E-04
 PROGRAM RESTART AT      801.175 SECONDS      DX = 330.00  DZ = 330.00
```

- APPENDIX D -

The Plume Model Code Listing

```
 INTEGER BUFL,CF,CF1,CFB,CFC,CFI,CFL,CFR,CFS,CFT,CQF,ERF,TD,VNTP,
1    VTP
 REAL NU,LIQ,LIQO,LIQI,LOUT
 DIMENSION CF(1),CQ(1),QCON(1),P(1),RX(1),RZ(1),TQ(1),TS(1),U(1),
1    W(1),ER(1),FFX3(102),FFY3(102),PBTIM(2),UO(1),WO(1),TQO(1),
2    TSO(1),SIE(1),SIEO(1),CHI(1),CHIO(1)
A,VAP(1),VAPO(1),LIQ(1),LIQO(1)
3    ,TYMF(25),FN(25),TYMT1(25),T1N(25),TYMT2(25),T2N(25),
4    COFBA(25),COFBB(25),COFBC(25),COFTA(25),COFTB(25),COFTC(25),
5    COFRA(25),COFRB(25),COFRC(25),COFLA(25),COFLB(25),COFLC(25),
6    OFOBTA(25),OFOBTB(25),OFOBTC(25),
7    OFOBRA(25),OFOBRB(25),OFOBRC(25),TAU(10),USL(32),USLOB(20),
8    USROB(20),USTOB(20),USBOB(20)
9,COFBD(25),COFBE(25),COFTD(25),COFTE(25),COFTF(25),COFBF(25),
*COFRD(25),COFRE(25),COFLD(25),COFLE(25),COFRF(25),COFLF(25),
AOFOBTD(25),OFOBTE(25),OFOBRD(25),OFOBRE(25),
B  OFOBTF(25),OFOBRF(25),
CTYMT3(25),TYMT4(25),TYMT5(25),T3N(25),T4N(25),T5N(25),
*   IICFR(1),IICFL(1),IICFT(1),IICFB(1)
*    ,ZERO1(1165),ZERO2(608),ZERO3(16),ZERO4(3)
 DIMENSION ZSIE(22),ZTQ(22),ZTS(22),ZVP(22),ZLQ(22),ZAP(22),WSP(22)
 DIMENSION TRSTRT(5),WZSIE(100),WZTQ(100),WZTS(100)
A,WZVP(100),WZLQ(100),WZAP(100),WWSP(100)
 COMMON/VRCOM/A(14000)
 COMMON/RGB/RLAMB,CHII,GAMX,NRSTRT,TRSTRT,ZSIE,ZTQ,ZTS,WZSIE,WZTQ,
AWZTS,NPROF,WZVP,WZLQ,ZVP,ZLQ,GAML,GAMV,VAPI,LIQI
B,WSP,WWSP,BKGND,DWNDS
 COMMON /VRCON/ ALP,ALPO,ALX,ALZ,BO,BETA,BUFL,CFI(9),CFS(9),CYL,
1    DT,DX,DZ,EM6,EPS,ERF,FSLIP,GAM,GAM1,GX,GZ,HDX,HDZ,I,I1,I2,I2K2,
2    IBP1,IBP2,IBR,IDATIN,IDIAG,IKP2,IOBS,IRSTRT,ITAPW,ITER,IVDI,
3    IVDO,K,K1,K2,K2NC,KBP1,KBP2,KBR,KNC,KWB,KWL,KWR,KWT,LABEL(20),
4    LPR,MODEL,NCYC,NCYCB,NPRT,NU,NWPC,RDT,RDX,RDZ,RDZS,
*    RIBKB,ROI,TD,TIMET,TIOSUM,TPL,TPLT,TPR,TPRT,TQI
5    ,TSI,TTD,TWTD,UI,WI,USR(32),UST(22),USB(22),USO(10),FFX3,FFY3
6    ,AW,BW,CW,EPSB,UBLI,UBRI,WBBI,WBTI,WEPS,WOBI,NTPAS,TGAM,CSUBP,
7    TO,SIEI,IDG,KDG,TI,MAT,RHOO,AT,TMU,TK,TYMF,FN,TYMT1,TIN,
8    TYMT2,T2N,RPRAN,NRESEX,NFLOW,NT1,NT2,TSTEP,KDERBC,UOBI,COFBA,
9    COFBB,COFBC,COFTA,COFTB,COFTC,COFRA,COFRB,COFRC,COFLA,COFLB,
*    COFLC,OFOBTA,OFOBTB,OFOBTC,OFOBRA,OFOBRB,OFOBRC,TAU,NTAU,USL,
1    USLOB,USROB,USTOB,USBOB,UMAX,WMAX
*   ,CSUBPO,EPSO,RDXDZS,RLENGH ,TQJET,TSJET
 COMMON /FLMCON/ DROU,DROUO,IPRFM
 COMMON /VRMAT3/ AI,BI,CI,AR,BR,CR,AMU,BMU,CMU,AK,BK,CK,ACP,BCP,CCP
1                ,VMIN
  COMMON/PROP/SIGN
 COMMON/EXTRA/NT3,NT4,NT5,TYMT3,TYMT4,TYMT5,T3N,T4N,T5N,COFBD,
1COFBE,COFBF,COFTD,COFTE,COFTF,COFRD,COFRE,COFRF,COFLD,COFLE,
2COFLF,OFOBTD,OFOBTE,OFOBTF,OFOBRD,OFOBRE,OFOBRF,IRESET,
*NCYCLS,TADD,NIV,IOBRAN
  COMMON/INDEX/NWPCL,K2NCL
  COMMON/LARGE/DIFFCO(2400)
 EQUIVALENCE (A(1),CF),(A(2),U),(A(3),W),(A(4),P),(A(5),TQ),
1    (A(6),TS),(A(7),ER,CQ),(A(8),UO),(A(9),WO),(A(10),TQO),
2    (A(11),TSO),(A(12),SIE),(A(13),SIEO),(A(14),RX),(A(15),RZ),
3    (A(16),IICFR),(A(17),IICFL),(A(18),IICFT),(A(19),IICFB),
```

```
      A   (A(20),CHI),(A(21),CHIO),
      B   (A(22),VAP),(A(23),VAPO),(A(24),LIQ),(A(25),LIQO),
      4   (ZERO1(1),ALP),(ZERO2(1),NT3),(ZERO3(1),AI),(ZERO4(1),DROU)
C NOTE. END - END OF NON-EXECUTABLE STATEMENTS .
C
C NOTE. NWPC = NUMBER OF WORDS PER MESH CELL .
      CALL ERASE (ZERO1,1165,ZERO2,608,ZERO3,16,ZERO4,3,A,14000)
      NWPC=25
      NWPCL = 4
      IVDI=5
      IVDO=6
  100 WRITE(IVDO,1)
      READ(IVDI,2) IBR,KBR,IPRFM,NCYCLS,TADD,IRESET,MODEL
      ERF=0
      IF( IPRFM.GT.0 ) CALL FLMINI
      IF( IBR ) 700,400,400
 400  PRINT 11
      CALL VSET
      WRITE(IVDO,3)
      IF( ERF.EQ.1 ) GO TO 700
      PRINT 12
      CALL VM
      IF( ERF.EQ.1 ) GO TO 700
      GO TO 100
  700 IF( IPRFM.GT.0 ) CALL FLMFIN
C ***** FORMATS ***** FORMATS ***** FORMATS ***** .
    1 FORMAT(1H1,22H MAIN PROGRAM CALLED .)
   2  FORMAT(2(5X,I5),7X,I2,I11,F10.4,5X,I5,5X,I2)
  3   FORMAT(1H ,27H SUBROUTINE VSET FINISHED .)
  11  FORMAT(1H ,25H SUBROUTINE VSET CALLED .)
  12  FORMAT(1H ,23H SUBROUTINE VM CALLED .)
      STOP
      END
      BLOCK DATA
      COMMON/LARGE/DIFFCO(2400)
      REAL DIFFCO/2400*1.0/
      END
      SUBROUTINE IDLE
      INTEGER BUFL,CF,CF1,CFB,CFC,CFI,CFL,CFR,CFS,CFT,CQF,ERF,TD,VNTP,
     1   VTP
      REAL NU,LIQ,LIQO,LIQI,LOUT
      DIMENSION CF(1),CQ(1),QCON(1),P(1),RX(1),RZ(1),TQ(1),TS(1),U(1),
     1   W(1),ER(1),FFX3(102),FFY3(102),PBTIM(2),UO(1),WO(1),TQO(1),
     2   TSO(1),SIE(1),SIEO(1),CHI(1),CHIO(1)
     A,VAP(1),VAPO(1),LIQ(1),LIQO(1)
     3   ,TYMF(25),FN(25),TYMT1(25),T1N(25),TYMT2(25),T2N(25),
     4   COFBA(25),COFBB(25),COFBC(25),COFTA(25),COFTB(25),COFTC(25),
     5   COFRA(25),COFRB(25),COFRC(25),COFLA(25),COFLB(25),COFLC(25),
     6   OFOBTA(25),OFOBTB(25),OFOBTC(25),
     7   OFOBRA(25),OFOBRB(25),OFOBRC(25),TAU(10),USL(32),USLOB(20),
     8   USROB(20),USTOB(20),USBOB(20)
     9,COFBD(25),COFBE(25),COFTD(25),COFTE(25),COFTF(25),COFBF(25),
     *COFRD(25),COFRE(25),COFLD(25),COFLE(25),COFRF(25),COFLF(25),
     AOFOBTD(25),OFOBTE(25),OFOBRD(25),OFOBRE(25),
     B  OFOBTF(25),OFOBRF(25),
```

```
     CTYMT3(25),TYMT4(25),TYMT5(25),T3N(25),T4N(25),T5N(25),
     *  IICFR(1),IICFL(1),IICFT(1),IICFB(1)
     *   ,ZERO1(1165),ZERO2(608),ZERO3(16),ZERO4(3)
      DIMENSION ZSIE(22),ZTQ(22),ZTS(22),ZVP(22),ZLQ(22),ZAP(22).WSP(22)
      DIMENSION TRSTRT(5),WZSIE(100),WZTQ(100),WZTS(100)
     A,WZVP(100),WZLQ(100),WZAP(100),WWSP(100)
      COMMON/VRCOM/A(14000)
      COMMON/RGB/RLAMB,CHII,GAMX,NRSTRT,TRSTRT,ZSIE,ZTQ,ZTS,WZSIE,WZTQ,
     AWZTS,NPROF,WZVP,WZLQ,ZVP,ZLQ,GAML,GAMV,VAPI,LIQI
     B,WSP,WWSP,BKGND,DWNDS
      COMMON /VRCON/ ALP,ALPO,ALX,ALZ,BO,BETA,BUFL,CFI(9),CFS(9),CYL,
     1    DT,DX,DZ,EM6,EPS,ERF,FSLIP,GAM,GAM1,GX,GZ,HDX,HDZ,I,I1,I2,I2K2,
     2    IBP1,IBP2,IBR,IDATIN,IDIAG,IKP2,IOBS,IRSTRT,ITAPW,ITER,IVDI,
     3    IVDO,K,K1,K2,K2NC,KBP1,KBP2,KBR,KNC,KWB,KWL,KWR,KWT,LABEL(20),
     4    LPR,MODEL,NCYC,NCYCB,NPRT,NU,NWPC,RDT,RDX,RDZ,RDZS,
     *    RIBKB,ROI,TD,TFIN,TIMET,TIOSUM,TPL,TPLT,TPR,TPRT,TQI
     5    ,TSI,TTD,TWTD,UI,WI,USR(32),UST(22),USB(22),USO(10),FFX3,FFY3
     6    ,AW,BW,CW,EPSB,UBLI,UBRI,WBBI,WBTI,WEPS,WOBI,NTPAS,TGAM,CSUBP,
     7    TO,SIEI,IDG,KDG,TI,MAT,RHOO,AT,TMU,TK,TYMF,FN,TYMT1,T1N,TYMT2,
     8    T2N,RPRAN,NRESEX,NFLOW,NT1,NT2,TSTEP,KDERBC,UOBI,COFBA,COFBB,
     9    COFBC,COFTA,COFTB,COFTC,COFRA,COFRB,COFRC,COFLA,COFLB,COFLC,
     *    OFOBTA,OFOBTB,OFOBTC,OFOBRA,OFOBRB,OFOBRC,TAU,NTAU,USL,
     1    USLOB,USROB,USTOB,USBOB,UMAX,WMAX
     *   ,CSUBPO,EPSO,RDXDZS,RLENGH ,TQJET,TSJET
      COMMON /FLMCON/ DROU,DROUO,IPRFM
      COMMON /VRMAT3/ AI,BI,CI,AR,BR,CR,AMU,BMU,CMU,AK,BK,CK,ACP,BCP,CCP
     1                ,VMIN
        COMMON/PROP/SIGN
      COMMON/EXTRA/NT3,NT4,NT5,TYMT3,TYMT4,TYMT5,T3N,T4N,T5N,COFBD,
     1COFBE,COFBF,COFTD,COFTE,COFTF,COFRD,COFRE,COFRF,COFLD,COFLE,
     2COFLF,OFOBTD,OFOBTE,OFOBTF,OFOBRD,OFOBRE,OFOBRF,IRESET,
     *NCYCLS,TADD,NIV,IOBRAN
        COMMON/INDEX/NWPCL,K2NCL
        COMMON/LARGE/DIFFCO(2400)
      EQUIVALENCE (A(1),CF),(A(2),U),(A(3),W),(A(4),P),(A(5),TQ),
     1    (A(6),TS),(A(7),ER,CQ),(A(8),UO),(A(9),WO),(A(10),TQO),
     2    (A(11),TSO),(A(12),SIE),(A(13),SIEO),(A(14),RX),(A(15),RZ),
     3    (A(16),IICFR),(A(17),IICFL),(A(18),IICFT),(A(19),IICFB),
     A    (A(20),CHI),(A(21),CHIO),
     B    (A(22),VAP),(A(23),VAPO),(A(24),LIQ),(A(25),LIQO),
     4    (ZERO1(1),ALP),(ZERO2(1),NT3),(ZERO3(1),AI),(ZERO4(1),DROU
      ENTRY TAPREA
      REWIND 8
       READ(8) A,ZERO1,ZERO2,ZERO4,NWPCL
      WRITE(IVDO,50) TD,TIMET,NCYC
      IDATIN=1
      NCYCB=NCYC
      IRSTRT=1
C *****FORMATS ***** FORMATS ***** FORMATS *****
   50 FORMAT(1H ,19H TAPE FILE NUMBER =,I4,9H  TIMET =,1PE12.4,
     1    16H  CYCLE NUMBER =,I6)
      RETURN
      ENTRY TAPWRI
      TD=TD+1
      ITW=ITAPW
```

```
      REWIND 8
      WRITE(8) A,ZERO1,ZERO2,ZERO4,NWPCL
      WRITE(IVDO,51) TD,TIMET,NCYC
C *****FORMATS ***** FORMATS ***** FORMATS *****
   51 FORMAT(1H ,19H TAPE FILE NUMBER =,I4,9H  TIMET =,1PE12.4,
     1  16H  CYCLE NUMBER =,I6)
      RETURN
      ENTRY COARSE
C  RESTART ON A COARSER MESH FOR IBR AND KBR EVEN ONLY
      IHALF=IBP2/2
      KHALF=KBP2/2
C  MANAGES ATMOSPHERIC PROFILES DURING RESTARTS ON A COARSER MESH
      DO 90 K=2,KHALF
      ZTQ(K)=(ZTQ(2*K-2)+ZTQ(2*K-1))/2.0
      ZTS(K)=(ZTS(2*K-2)+ZTS(2*K-1))/2.0
      ZLQ(K)=(ZLQ(2*K-2)+ZLQ(2*K-1))/2.0
      ZVP(K)=(ZVP(2*K-2)+ZVP(2*K-1))/2.0
      ZAP(K)=(ZAP(2*K-2)+ZAP(2*K-1))/2.0
      WSP(K)=(WSP(2*K-2)+WSP(2*K-1))/2.0
   90 ZSIE(K)=(ZSIE(2*K-2)+ZSIE(2*K-1))/2.0
      ZSIE(1)=ZSIE(2)
      ZTS(1)=ZTS(2)
      ZTQ(1)=ZTQ(2)
      ZLQ(1)=ZLQ(2)
      ZVP(1)=ZVP(2)
      ZAP(1)=ZAP(2)
      WSP(1)=WSP(2)
      KHP1=KHALF+1
      DO 95 K=KHP1,KBP1
      ZTQ(K)=WZTQ((NRSTRT*KBR/2)+K-1)
      ZTS(K)=WZTS((NRSTRT*KBR/2)+K-1)
      ZLQ(K)=WZLQ((NRSTRT*KBR/2)+K-1)
      ZVP(K)=WZVP((NRSTRT*KBR/2)+K-1)
      ZAP(K)=WZAP((NRSTRT*KBR/2)+K-1)
      WSP(K)=WWSP((NRSTRT*KBR/2)+K-1)
   95 ZSIE(K)=WZSIE((NRSTRT*KBR/2)+K-1)
      ZSIE(KBP2)=ZSIE(KBP1)
      ZTS(KBP2)=ZTS(KBP1)
      ZTQ(KBP2)=ZTQ(KBP1)
      ZLQ(KBP2)=ZLQ(KBP1)
      ZVP(KBP2)=ZVP(KBP1)
      ZAP(KBP2)=ZAP(KBP1)
      WSP(KBP2)=WSP(KBP1)
C  RECOMPUTES DATA ASSOCIATED WITH DZ, DX FOR USE IN VM
      DX=2.0*DX
      DZ=2.0*DZ
      RDX=1./DX
      RDZ=1./DZ
      HDX=.5*DX
      HDZ=.5*DZ
      RDZS=1./(DZ*DZ)
      BETA=.5*B0/(RDX*RDX+RDZ*RDZ)
      EPSB=4.*NU/AMIN1(DX,DZ)
      RDXDZS=1./(RDX*RDX+RDZ*RDZ)
      X1=FLOAT(IBR)*DX
```

```
      Z1=FLOAT(KBR)*DZ
      RLENGH=1./AMAX1(X1,Z1)
C  BEGINS CELL BY CELL AVERAGING
      DO 100 I=2,IBP1
      DO 100 K=2,KBP1
      IK=1+NWPC*(((I-1)*KBP2)+K-1)
      IF(I.GT.IHALF.OR.K.GT.KHALF) GO TO 200
C  COMPUTES INDICES FOR FLUID CELLS
      J=2*(I-1)
      L=2*(K-1)
      IKR=1+NWPC*(((J-1)*KBP2)+L-1)
      J=2*I-1
      IPKR=1+NWPC*(((J-1)*KBP2)+L-1)
      L=2*K-1
      IPKPR=1+NWPC*(((J-1)*KBP2)+L-1)
      J=2*(I-1)
      IKPR=1+NWPC*(((J-1)*KBP2)+L-1)
C  COMPUTES FLUID CELL DENSITIES FOR CELL MASS AVERAGING
      CIT=CI-SIE(IKR)
      TEMPLL=SI(AI,BI,CIT,-1)
      CIT=CI-SIE(IPKR)
      TEMPLR=SI(AI,BI,CIT,-1)
      CIT=CI-SIE(IKPR)
      TEMPUL=SI(AI,BI,CIT,-1)
      CIT=CI-SIE(IPKPR)
      TEMPUR=SI(AI,BI,CIT,-1)
      RHOLL=AR*TEMPLL*TEMPLL+BR*TEMPLL+CR
      RHOLR=AR*TEMPLR*TEMPLR+BR*TEMPLR+CR
      RHOUL=AR*TEMPUL*TEMPUL+BR*TEMPUL+CR
      RHOUR=AR*TEMPUR*TEMPUR+BR*TEMPUR+CR
      RHOSUM=RHOLL+RHOLR+RHOUL+RHOUR
C  MASS AVERAGING OF FLUID CELLS FOR RESTART ON COARSER MESH
      U(IK)=(U(IKR)*RHOLL+U(IPKR)*RHOLR+U(IKPR)*RHOUL+U(IPKPR)*RHOUR)/RH
     AOSUM
      UO(IK)=(UO(IKR)*RHOLL+UO(IPKR)*RHOLR+UO(IKPR)*RHOUL+UO(IPKPR)
     A*RHOUR)/RHOSUM
      W(IK)=(W(IKR)*RHOLL+W(IPKR)*RHOLR+W(IKPR)*RHOUL+W(IPKPR)*RHOUR)/RH
     AOSUM
      WO(IK)=(WO(IKR)*RHOLL+WO(IPKR)*RHOLR+WO(IKPR)*RHOUL+WO(IPKPR)
     A*RHOUR)/RHOSUM
      TS(IK)=(TS(IKR)+TS(IPKR)+TS(IKPR)+TS(IPKPR))/4.00
      TSO(IK)=(TSO(IKR)+TSO(IPKR)+TSO(IKPR)+TSO(IPKPR))/4.0
      TQ(IK)=(TQ(IKR)*RHOLL+TQ(IPKR)*RHOLR+TQ(IKPR)*RHOUL+TQ(IPKPR)
     A*RHOUR)/RHOSUM
      TQO(IK)=(TQO(IKR)*RHOLL+TQO(IPKR)*RHOLR+TQO(IKPR)*RHOUL+TQO(IPKPR)
     A*RHOUR)/RHOSUM
      SIE(IK)=(SIE(IKR)*RHOLL+SIE(IPKR)*RHOLR+SIE(IKPR)*RHOUL+SIE(IPKPR)
     A*RHOUR)/RHOSUM
      SIEO(IK)=(SIEO(IKR)*RHOLL+SIEO(IPKR)*RHOLR+SIEO(IKPR)*RHOUL+SIEO(I
     APKPR)*RHOUR)/RHOSUM
      CHI(IK)=(CHI(IKR)+CHI(IPKR)+CHI(IKPR)+CHI(IPKPR))/4.0
      CHIO(IK)=(CHIO(IKR)+CHIO(IPKR)+CHIO(IKPR)+CHIO(IPKPR))/4.0
      VAP(IK)=(VAP(IKR)+VAP(IPKR)+VAP(IKPR)+VAP(IPKPR))/4.0
      VAPO(IK)=(VAPO(IKR)+VAPO(IPKR)+VAPO(IKPR)+VAPO(IPKPR))/4.0
      LIQ(IK)=(LIQ(IKR)+LIQ(IPKR)+LIQ(IKPR)+LIQ(IPKPR))/4.0
```

```
      LIQO(IK)=(LIQO(IKR)+LIQO(IPKR)+LIQO(IKPR)+LIQO(IPKPR))/4.0
      P(IK)=0.0
      GO TO 100
C  INITIALIZATION OF CELLS THAT WEREN'T IN THE PREVIOUS RUN
  200 U(IK)=0.0
      UO(IK)=0.0
      W(IK)=0.0
      WO(IK)=0.0
      SIE(IK)=ZSIE(K)
      SIEO(IK)=ZSIE(K)
      TS(IK)=ZTS(K)
      TSO(IK)=ZTS(K)
      TQ(IK)=ZTQ(K)
      TQO(IK)=ZTQ(K)
      CHI(IK)=BKGND
      CHIO(IK)=BKGND
      LIQ(IK)=ZLQ(K)
      LIQO(IK)=ZLQ(K)
      VAP(IK)=ZVP(K)
      VAPO(IK)=ZVP(K)
      P(IK)=0.0
  100 CONTINUE
      RETURN
      ENTRY FILMCO
      RETURN
      ENTRY FLMCAL
      RETURN
      ENTRY FLMINI
      RETURN
      ENTRY FLMFIN
      RETURN
      ENTRY FLMGEN
      RETURN
      ENTRY VREQ
      RETURN
      ENTRY VRFLM
      RETURN
      END
      FUNCTION SI(XTBL,YTBL,X,N)
      COMMON/PROP/SIGN
      DIMENSION XTBL(1),YTBL(1)
      IF( N.LT.0 ) GO TO 200
      IF(X.LT.XTBL(1)) GO TO 16
      IF(X.GT.XTBL(N)) GO TO 31
      DO 10 I=1,N
      IF(X.EQ.XTBL(I)) GO TO 21
      IF(X.LT.XTBL(I)) GO TO 26
   10 CONTINUE
   16 J1 = 1
      J2 = 2
      GO TO 50
   21 SI = YTBL(I)
      GO TO 100
   26 J1 = I-1
      J2 = I
```

```
      GO TO 50
   31 J1 = N-1
      J2 = N
   50 SI=YTBL(J1)+(YTBL(J2)-YTBL(J1))*(X-XTBL(J1))/(XTBL(J2)-XTBL(J1))
  100 RETURN
C NOTE. ROOTS OF QUADRATIC EQUATION - A*X**2 + B*X + C =0.0 .
  200 A=XTBL(1)
      B=YTBL(1)
      C=X
       IF(A.NE.0.0) GO TO 205
       SI=-1.0*C/B
       RETURN
 205   CONTINUE
      D=B*B - 4.*A*C
      IF( D ) 210,220,220
  210 PRINT 211
      RETURN
  220 DS=SQRT( D )
      IF (SIGN) 224,224,226
  224 SI = -1.0 * (B + DS) / (2.0 * A)
      GO TO 230
  226 SI = (DS - B) / (2.0 * A)
      GO TO 230
  230 CONTINUE
      RETURN
C ***** FORMATS ***** FORMATS ***** FORMATS ***** .
  211 FORMAT(1H ,28H ERROR - ROOTS ARE COMPLEX .)
      END
      SUBROUTINE VRPRT
      DIMENSION TPT(50,50)
      INTEGER BUFL,CF,CF1,CFB,CFC,CFI,CFL,CFR,CFS,CFT,CQF.ERF,TD,VNTP,
     1VTP,CFOUT
      REAL NU,LIQ,LIQO,LIQI,LOUT
      DIMENSION UOUT(7),VOUT(7),IOUT(7),KOUT(7),CFOUT(7),QOUT(7),
     1SOUT(7),TOUT(7),XOUT(7),GOUT(7),LOUT(7),VSOUT(7),ROUT(7),
     2 REH(4)
      DIMENSION CF(1),CQ(1),QCON(1),P(1),RX(1),RZ(1),TQ(1),TS(1),U(1),
     1   W(1),ER(1),FFX3(102),FFY3(102),PBTIM(2),UO(1),WO(1),TQO(1),
     2   TSO(1),SIE(1),SIEO(1),CHI(1),CHIO(1)
     A,VAP(1),VAPO(1),LIQ(1),LIQO(1)
     3   ,TYMF(25),FN(25),TYMT1(25),T1N(25),TYMT2(25),T2N(25),
     4   COFBA(25),COFBB(25),COFBC(25),COFTA(25),COFTB(25),COFTC(25),
     5   COFRA(25),COFRB(25),COFRC(25),COFLA(25),COFLB(25),COFLC(25),
     6   OFOBTA(25),OFOBTB(25),OFOBTC(25),
     7   OFOBRA(25),OFOBRB(25),OFOBRC(25),TAU(10),USL(32),USLOB(20),
     8   USROB(20),USTOB(20),USBOB(20)
     9,COFBD(25),COFBE(25),COFTD(25),COFTE(25),COFTF(25),COFBF(25),
     *COFRD(25),COFRE(25),COFLD(25),COFLE(25),COFRF(25),COFLF(25),
     AOFOBTD(25),OFOBTE(25),OFOBRD(25),OFOBRE(25),
     B  OFOBTF(25),OFOBRF(25),
     CTYMT3(25),TYMT4(25),TYMT5(25),T3N(25),T4N(25),T5N(25),
     *  IICFR(1),IICFL(1),IICFT(1),IICFB(1)
     *   ,ZERO1(1165),ZERO2(608),ZERO3(16),ZERO4(3)
      DIMENSION ZSIE(22),ZTQ(22),ZTS(22),ZVP(22),ZLQ(22),ZAP(22),WSP(22)
      DIMENSION TRSTRT(5),WZSIE(100),WZTQ(100),WZTS(100)
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     A,WZVP(100),WZLQ(100),WZAP(100),WWSP(100)
      COMMON/VRCOM/A(14000)
      COMMON/HAMZA/ZAP
      COMMON/RGB/RLAMB,CHII,GAMX,NRSTRT,TRSTRT,ZSIE,ZTQ,ZTS,WZSIE,WZTQ,
     AWZTS,NPROF,WZVP,WZLQ,ZVP,ZLQ,GAML,GAMV,VAPI,LIQI
     B,WSP,WWSP,BKGND,DWNDS
      COMMON /VRCON/ ALP,ALPO,ALX,ALZ,BO,BETA,BUFL,CFI(9),CFS(9),CYL,
     1   DT,DX,DZ,EM6,EPS,ERF,FSLIP,GAM,GAM1,GX,GZ,HDX,HDZ,I,I1,I2,I2K2,
     2   IBP1,IBP2,IBR,IDATIN,IDIAG,IKP2,IOBS,IRSTRT,ITAPW,ITER,IVDI,
     3   IVDO,K,K1,K2,K2NC,KBP1,KBP2,KBR,KNC,KWB,KWL,KWR,KWT,LABEL(20),
     4   LPR,MODEL,NCYC,NCYCB,NPRT,NU,NWPC,RDT,RDX,RDZ,RDZS,
     *   RIBKB,ROI,TD,TFIN,TIMET,TIOSUM,TPL,TPLT,TPR,TPRT,TQI
     5   ,TSI,TTD,TWTD,UI,WI,USR(32),UST(22),USB(22),USO(10),
     *   FFX3,FFY3
     6   ,AW,BW,CW,EPSB,UBLI,UBRI,WBBI,WBTI,WEPS,WOBI,NTPAS,TGAM,CSUBP,
     7   TO,SIEI,IDG,KDG,TI,MAT,RHOO,AT,TMU,TK,TYMF,FN,TYMT1,T1N,TYMT2,
     8   T2N,RPRAN,NRESEX,NFLOW,NT1,NT2,TSTEP,KDERBC,UOBI,COFBA,COFBB,
     9   COFBC,COFTA,COFTB,COFTC,COFRA,COFRB,COFRC,COFLA,COFLB,COFLC,
     *   OFOBTA,OFOBTB,OFOBTC,OFOBRA,OFOBRB,OFOBRC,TAU,NTAU,USL,
     1   USLOB,USRO3,USTOB,USBOB,UMAX,WMAX
     *  ,CSUBPO,EPSO,RDXDZS,RLENGH ,TQJET,TSJET
      COMMON /VRMAT3/ AI,BI,CI,AR,BR,CR,AMU,BMU,CMU,AK,BK,CK,ACP,BCP,CCP
     1                ,VMIN
       COMMON/PROP/SIGN
      COMMON/EXTRA/NT3,NT4,NT5,TYMT3,TYMT4,TYMT5,T3N,T4N,T5N,COFBD,
     1COFBE,COFBF,COFTD,COFTE,COFTF,COFRD,COFRE,COFRF,COFLD,COFLE,
     2COFLF,OFOBTD,OFOBTE,OFOBTF,OFOBRD,OFOBRE,OFOBRF,IRESET,
     *NCYCLS,TADD,NIV,IOBRAN
       COMMON/INDEX/NWPCL,K2NCL
      COMMON /FLMCON/ DROU,DROUO,IPERM
       COMMON/LARGE/DIFFCO(2400)
      EQUIVALENCE (A(1),CF),(A(2),U),(A(3),W),(A(4),P),(A(5),TQ),
     1   (A(6),TS),(A(7),ER,CQ),(A(8),UO),(A(9),WO),(A(10),TQO),
     2   (A(11),TSO),(A(12),SIE),(A(13),SIEO),(A(14),RX),(A(15),RZ),
     3   (A(16),IICFR),(A(17),IICFL),(A(18),IICFT),(A(19),IICFB),
     A   (A(20),CHI),(A(21),CHIO),
     B   (A(22),VAP),(A(23),VAPO),(A(24),LIQ),(A(25),LIQO),
     4   (ZERO1(1),ALP),(ZERO2(1),NT3),(ZERO3(1),AI),(ZERO4(1),DROU)
      DATA REH/'V   ','V10 ','V20 ','    '/
C NOTE. END - END OF NON-EXECUTABLE STATEMENTS .
C     PRODUCES A CELL BY CELL OUTPUT OF STORED VARIABLES (22 X 22 ONLY)
      WRITE(IVDO,5)
      WRITE(IVDO,88) ZAP
   88 FORMAT(6E12.4)
   96 DO 103 ILOOP=1,4
      IREST=(ILOOP-1)*5
   97 DO 102 KLOOP=1,5
      KREST=(KLOOP-1)*5
   98 DO 100 KINV=1,5
      K=23-KINV-KREST
      IF(K.EQ.0) GO TO 101
      DO 99 IPART=1,7
      I=IPART+IREST
      IK=1+NWPC*(((I-1)*KBP2)+K-1)
      UOUT(IPART)=U(IK)
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      VOUT(IPART)=W(IK)                                                 PLU04410
      IOUT(IPART)=I                                                     PLU04420
      KOUT(IPART)=K                                                     PLU04430
      CFOUT(IPART)=CF(IK)                                               PLU04440
      QOUT(IPART)=TQ(IK)                                                PLU04450
      SOUT(IPART)=TS(IK)                                                PLU04460
      XOUT(IPART)=CHI(IK)                                               PLU04470
      GOUT(IPART)=VAP(IK)                                               PLU04480
      LOUT(IPART)=LIQ(IK)                                               PLU04490
      SIEC=SIE(IK)                                                      PLU04500
      CIT=CI-SIEC                                                       PLU04510
      TOUT(IPART)=SI(AI,BI,CIT,-1)                                      PLU04520
      IF(K.EQ.1) GO TO 115                                              PLU04530
      IF(K.EQ.22) GO TO 115                                             PLU04540
      RHOC=AR*TOUT(IPART)*TOUT(IPART)+BR*TOUT(IPART)+CR                 PLU04550
      ABT=(TOUT(IPART)+459.7)*((ZAP(K)/1000.)**.2856)/(1.+0.61*VAP(IK)/ PLU04560
     1 RHOC)/1.8                                                        PLU04570
      EVAP=10.**(-2937.4/ABT-4.9283*ALOG10(ABT)+23.5518)                PLU04580
      ROUT(IPART)=RHOC*0.61*EVAP/ZAP(K)*(TOUT(IPART)+459.7)/(ABT*1.8)   PLU04590
      VSOUT(IPART)=GOUT(IPART)/ROUT(IPART)                              PLU04600
  115 IF(CF(IK).GE.30) TOUT(IPART)=P(IK)                                PLU04610
   99 CONTINUE                                                          PLU04620
      WRITE(IVDO,20) (VOUT(L),L=1,7)                                    PLU04630
      DO 17 IPART=1,7                                                   PLU04640
      IF(VSOUT(IPART) .LT. 0.99) GO TO 202                              PLU04650
      VSOUT(IPART)=REH(1)                                               PLU04660
      GO TO 17                                                          PLU04670
  202 IF(VSOUT(IPART) .LE. 0.9) GO TO 203                               PLU04680
      VSOUT(IPART)=REH(2)                                               PLU04690
      GO TO 17                                                          PLU04700
  203 IF(VSOUT(IPART) .LE. 0.8) GO TO 206                               PLU04710
      VSOUT(IPART)=REH(3)                                               PLU04720
      GO TO 17                                                          PLU04730
  206 VSOUT(IPART)=REH(4)                                               PLU04740
   17 CONTINUE                                                          PLU04750
      WRITE(IVDO,15) (VSOUT(L),L=1,7)                                   PLU04760
      WRITE(IVDO,30) (IOUT(L),KOUT(L),L=1,7)                            PLU04770
      WRITE(IVDO,40) (TOUT(L),L=1,7)                                    PLU04780
      WRITE(IVDO,45) (ROUT(L),L=1,7)                                    PLU04790
      WRITE(IVDO,50) (CFOUT(L),UOUT(L),L=1,7)                           PLU04800
      WRITE(IVDO,70) (SOUT(L),L=1,7)                                    PLU04810
      WRITE(IVDO,60) (QOUT(L),L=1,7)                                    PLU04820
      WRITE(IVDO,80) (XOUT(L),L=1,7)                                    PLU04830
      WRITE(IVDO,85) (GOUT(L),L=1,7)                                    PLU04840
      WRITE(IVDO,90) (LOUT(L),L=1,7)                                    PLU04850
  100 CONTINUE                                                          PLU04860
  101 WRITE(IVDO,7) TIMET,NCYC,ITER,DT                                  PLU04870
      WRITE(IVDO,5)                                                     PLU04880
  102 CONTINUE                                                          PLU04890
  103 CONTINUE                                                          PLU04900
      RETURN                                                            PLU04910
    5 FORMAT('1')                                                       PLU04920
    7 FORMAT(1H ,5HTIME=,1PE12.4,3H  , ,14HCYCLE NUMBER =,I5,3H  , ,    PLU04930
     1 28H PRESSURE ITERATION NUMBER =,I4,3H  , ,4HDT =,E12.4)          PLU04940
   10 FORMAT(' ',7('X',17X))                                            PLU04950
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```
15   FORMAT(' ',7('X',11X,A4,2X))                                          PLU04960
20   FORMAT(' ',7(5HXXXXX,1X,F7.3,1X,4HXXXX))                              PLU04970
30   FORMAT(' ',7(1HX,5X,'(',I2,',',I2,')',5X))                            PLU04980
40   FORMAT(' ',7(1HX,3X,F7.3,1X,' F',4X))                                 PLU04990
45   FORMAT(' ',7(1HX,2X,'RHS=',1PE10.3,1X))                               PLU05000
50   FORMAT(' ',3X,7(4X,I2,5X,F7.3))                                       PLU05010
60   FORMAT(' ',7(1HX,2X,'TKE=',1PE10.3,1X))                               PLU05020
70   FORMAT(' ',7(1HX,2X,'TNU=',1PE10.3,1X))                               PLU05030
80   FORMAT(' ',7(1HX,2X,'CHI=',1PE10.3,1X))                               PLU05040
85   FORMAT(' ',7(1HX,2X,'VAP=',1PE10.3,1X))                               PLU05050
90   FORMAT(' ',7(1HX,2X,'LIQ=',1PE10.3,1X))                               PLU05060
     END                                                                   PLU05070
     SUBROUTINE VSET                                                       PLU05080
     INTEGER BUFL,CF,CF1,CFB,CFC,CFI,CFL,CFR,CFS,CFT,COF,ERF,TD,VNTP,      PLU05090
    1   VTP                                                                PLU05100
     REAL NU,LIQ,LIQO,LIQI,LOUT                                            PLU05110
     DIMENSION CF(1),CQ(1),QCON(1),P(1),RX(1),RZ(1),TQ(1),TS(1),U(1),      PLU05120
    1   W(1),ER(1),FFX3(102),FFY3(102),PBTIM(2),UO(1),WO(1),TQO(1),        PLU05130
    2   TSO(1),SIE(1),SIEO(1),CHI(1),CHIO(1)                               PLU05140
    A,VAP(1),VAPO(1),LIQ(1),LIQO(1)                                        PLU05150
    3   ,TYMF(25),FN(25),TYMT1(25),T1N(25),TYMT2(25),T2N(25),              PLU05160
    4   COFBA(25),COFBB(25),COFBC(25),COFTA(25),COFTB(25),COFTC(25),       PLU05170
    5   COFRA(25),COFRB(25),COFRC(25),COFLA(25),COFLB(25),COFLC(25),       PLU05180
    6   OFOBTA(25),OFOBTB(25),OFOBTC(25),                                  PLU05190
    7   OFOBRA(25),OFOBRB(25),OFOBRC(25),TAU(10),USL(32),USLOB(20),        PLU05200
    8   USROB(20),USTOB(20),USBOB(20)                                      PLU05210
    9,COFBD(25),COFBE(25),COFTD(25),COFTE(25),COFTF(25),COFBF(25),         PLU05220
    *COFRD(25),COFRE(25),COFLD(25),COFLE(25),COFRF(25),COFLF(25),          PLU05230
    AOFOBTD(25),OFOBTE(25),OFOBRD(25),OFOBRE(25),                          PLU05240
    B  OFOBTF(25),OFOBRF(25),                                              PLU05250
    CTYMT3(25),TYMT4(25),TYMT5(25),T3N(25),T4N(25),T5N(25),                PLU05260
    *  IICFR(1),IICFL(1),IICFT(1),IICFB(1)                                 PLU05270
    *   ,ZERO1(1165),ZERO2(608),ZERO3(16),ZERO4(3)                         PLU05280
     DIMENSION ZSIE(22),ZTQ(22),ZTS(22),ZVP(22),ZLQ(22),ZAP(22),WSP(22)    PLU05290
     DIMENSION TRSTRT(5),WZSIE(100),WZTQ(100),WZTS(100)                    PLU05300
    A,WZVP(100),WZLQ(100),WZAP(100),WWSP(100)                              PLU05310
     COMMON/VRCOM/A(14000)                                                 PLU05320
     COMMON/RGB/RLAMB,CHII,GAMX,NRSTRT,TRSTRT,ZSIE,ZTQ,ZTS,WZSIE,WZTQ,     PLU05330
    AWZTS,NPROF,WZVP,WZLQ,ZVP,ZLQ,GAML,GAMV,VAPI,LIQI                      PLU05340
    B,WSP,WWSP,BKGND,DWNDS                                                 PLU05350
     COMMON /VRCON/ ALP,ALPO,ALX,ALZ,BO,BETA,BUFL,CFI(9),CFS(9),CYL,       PLU05360
    1   DT,DX,DZ,EM6,EPS,ERF,FSLIP,GAM,GAM1,GX,GZ,HDX,HDZ,I,I1,I2,I2K2,    PLU05370
    2   IBP1,IBP2,IBR,IDATIN,IDIAG,IKP2,IOBS,IRSTRT,ITAPW,ITER,IVDI,       PLU05380
    3   IVDO,K,K1,K2,K2NC,KBP1,KBP2,KBR,KNC,KWB,KWL,KWR,KWT,LABEL(20),     PLU05390
    4   LPR,MODEL,NCYC,NCYCB,NPRT,NU,NWPC,RDT,RDX,RDZ,RDZS,                PLU05400
    *   RIBKB,ROI,TD,TFIN,TIMET,TIOSUM,TPL,TPLT,TPR,TPRT,TQI               PLU05410
    5   ,TSI,TTD,TWTD,UI,WI,USR(32),UST(22),USB(22),USO(10),               PLU05420
    *   FFX3,FFY3                                                          PLU05430
    6   ,AW,BW,CW,EPSB,UBLI,UBRI,WBBI,WBTI,WEPS,WOBI,NTPAS,TGAM,CSUBP,     PLU05440
    7   TO,SIEI,IDG,KDG,TI,MAT,RHOO,AT,TMU,TK,TYMF,FN,TYMT1,T1N,TYMT2,     PLU05450
    8   T2N,RPRAN,NRESEX,NFLOW,NT1,NT2,TSTEP,KDERBC,UOBI,COFBA,COFBB,      PLU05460
    9   COFBC,COFTA,COFTB,COFTC,COFRA,COFRB,COFRC,COFLA,COFLB,COFLC,       PLU05470
    *   OFOBTA,OFOBTB,OFOBTC,OFOBRA,OFOBRB,OFOBRC,TAU,NTAU,USL,            PLU05480
    1   USLOB,USROB,USTOB,USBOB,UMAX,WMAX                                  PLU05490
    *  ,CSUBPO,EPSO,RDXDZS,RLENGH ,TQJET,TSJET                             PLU05500
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```
      COMMON /FLMCON/ DROU,DROUO,IPRFM
      COMMON /VRMAT3/ AI,BI,CI,AR,BR,CR,AMU,BMU,CMU,AK,BK,CK,ACP,BCP,CCP
     1                ,VMIN
       COMMON/PROP/SIGN
      COMMON/EXTRA/NT3,NT4,NT5,TYMT3,TYMT4,TYMT5,T3N,T4N,T5N,COFBD,
     1COFBE,COFBF,COFTD,COFTE,COFTF,COFRD,COFRE,COFRF,COFLD,COFLE,
     2COFLF,OFOBTD,OFOBTE,OFOBTF,OFOBRD,OFOBRE,OFOBRF,IRESET,
     *NCYCLS,TADD,NIV,IOBRAN
       COMMON/INDEX/NWPCL,K2NCL
       COMMON/LARGE/DIFFCO(2400)
      EQUIVALENCE (A(1),CF),(A(2),U),(A(3),W),(A(4),P),(A(5),TQ),
     1   (A(6),TS),(A(7),ER,CQ),(A(8),UO),(A(9),WO),(A(10),TQO),
     2   (A(11),TSO),(A(12),SIE),(A(13),SIEO),(A(14),RX),(A(15),RZ),
     3   (A(16),IICFR),(A(17),IICFL),(A(18),IICFT),(A(19),IICFB),
     A   (A(20),CHI),(A(21),CHIO),
     B   (A(22),VAP),(A(23),VAPO),(A(24),LIQ),(A(25),LIQO),
     4   (ZERO1(1),ALP),(ZERO2(1),NT3),(ZERO3(1),AI),(ZERO4(1),DROU)
C NOTE. END - END OF NON-EXECUTABLE STATEMENTS .
C
C
C NOTE. VSET IS RESPONSIBLE FOR MESH,PARTICLE AND FILM INITIALIZATION .
C
      IDATIN=0
      IF( IBR.EQ.0 ) CALL TAPREA
C NOTE. READS,WRITES PRIMARY INPUT DATA .
      READ(IVDI,1) LABEL
      READ(IVDI,2)    DT,TPRT,TPLT,TWTD,TFIN,ITAPW,NPRT,IDIAG,LPR,IOBS
     1 ,IDG,KDG
      WRITE(IVDO,50) IBR,KBR,IPRFM,NCYCLS,TADD,IRESET,MODEL
      WRITE(IVDO,1) LABEL
      WRITE(IVDO,51) DT,TPRT,TPLT,TWTD,TFIN,ITAPW,NPRT,IDIAG,LPR,IOBS
     1 ,IDG,KDG
      RDT=1./DT
      IF( IPRFM.LT.1 ) TPLT=2.*TFIN
      TPL=TPLT
      TPR=TPRT
      TTD=TWTD
      IF( IDATIN.LT.1 ) GO TO 100
      TIMET=TIMET+TADD
      TWTD=TIMET
      TPRT=TWTD
      TPLT=TPRT
      CALL MESHMK
      IF (IPRFM.LT.1) GO TO 500
      CALL FLMGEN
      CALL FILMCO
      GO TO 500
C NOTE. INITIALIZES CONSTANTS .
  100 TIMET=0.0
      IRSTRT=0
      TD=0
      NCYC=0
      NCYCB=0
      EM6=1.E-6
C NOTE. INITIALIZES CELL INDEX QUANTITIES .
```

```
      IBP1=IBR + 1
      KBP1=KBR+1
      IBP2=IBR+2
      KBP2=KBR+2
      I2K2=IBP2*KBP2*NWPC
      KNC=KBR*NWPC
      K2NC=KBP2*NWPC
      K2NCL = KBP2 * NWPCL
      IKP2=IBR*K2NC
      IKMX=I2K2 + 2*K2NC
      RIBKB=1./FLOAT(IBR*KBR)
C NOTE. GENERATES BOTH MESH AND FILM REGIONS , RESPECTIVELY .
      CALL MESHMK
      IF( IPRFM.LT.1 ) GO TO 2000
      CALL FLMGEN
      CALL FILMCO
2000  WRITE( IVDO,60)
  500  K2NCL=KBP2*NWPCL
      WRITE( IVDO,70)
       WRITE(IVDO,80)
      I1=2
      K1=2
      I2=IBP1
      K2 = KBP1
      KKL = 0
      KK = 0
      DO 511  I=I1,I2
      KK = KK + K2NC
      KKL = KKL + K2NCL
      LWPC = 1
      LWPCL = 1
      DO 510  K=K1,K2
      LWPC = LWPC + NWPC
      LWPCL = LWPCL + NWPCL
      IK = KK + LWPC
      IKL = KKL + LWPCL
      IPK = IK + K2NC
      IMK = IK - K2NC
      IKP = IK + NWPC
      IKM = IK - NWPC
      CFC = CF(IK)
      CFR = CF(IPK)
      CFL = CF(IMK)
      CFT = CF(IKP)
      CFB = CF(IKM)
      IF (CFC.NE.1) GO TO 510
      IF (CFR.NE.1) DIFFCO( IKL  ) = 0.0
      IF (CFL.NE.1) DIFFCO(IKL+2)= 0.0
      IF (CFT.NE.1) DIFFCO( IKL+1) = 0.0
      IF (CFB.NE.1) DIFFCO( IKL+3) = 0.0
      DCR = DIFFCO(IKL)
      DCT = DIFFCO(IKL+1)
      DCL = DIFFCO(IKL+2)
      DCB = DIFFCO(IKL+3)
       WRITE(IVDO,75) I,K,IK,IKL,CFC,CFR,CFT,CFL,CFB,DCR,DCT,DCL,DCB
```

```
 510 CONTINUE
511   CONTINUE
 520 RETURN
C ***** FORMATS ***** FORMATS ***** FORMATS ***** .
   1 FORMAT(20A4)
   2 FORMAT(5F8.3,5I2,2I3)
50    FORMAT(1H ,4X,4HIBR=,I5,/,5X,4HKBR=,I5,/,3X,6HIPRFM=,I2,/,5X,
    1 8HNCYCLST=,I10,/,5X,5HTADD=,E12.5,5X,7HIRESET=,I5,5X,6HMODEL=,I2)
  51 FORMAT(1H ,5X,3HDT=,1PE12.5/4X,5HTPRT=,E12.5/4X,5HTPLT=,E12.5/
    1 4X,5HTWTD=,E12.5/4X,5HTFIN=,E12.5/3X,6HITAPW=,I2/4X,5HNPRT=,I2/
    2 3X,6HIDIAG=,I2/5X,4HLPR=,I2/4X,5HIOBS=,I2/5X,4HIDG=,I3/5X,4HKDG=,
    3 I3)
  52 FORMAT(1H ,104H *** ERROR 001 - MESH ARRAY A() IS DIMENSIONED TOO
    1SMALL FOR MESH PARAMETERS ,I.E.   IBR  AND  KBR . ***)
  60 FORMAT(1H ,53H NOTE. COMPLETION OF     VSET      - VARR II SET UP G
    1ENERATION .)
 70   FORMAT(1H1)
75      FORMAT(1H ,9I6,4F6.1)
80      FORMAT(1H ,5X,1HI,5X,1HK,4X,2HIK,3X,3HIKL,3X,3HCFC,3X,3HCFR,3X,
    1 3HCFT,3X,3HCFL,3X,3HCFB,3X,3HDCR,3X,3HDCT,3X,3HDCL,3X,3HDCB)
      END
      SUBROUTINE MESHMK
      INTEGER BUFL,CF,CF1,CFB,CFC,CFI,CFL,CFR,CFS,CFT,CQF,ERF,TD,VNTP,
     1    VTP
      REAL NU,LIQ,LIQO,LIQI,LOUT
      DIMENSION CF(1),CQ(1),QCON(1),P(1),RX(1),RZ(1),TQ(1),TS(1),U(1),
     1    W(1),ER(1),FFX3(102),FFY3(102),PBTIM(2),UO(1),WC(1),TQO(1),
     2    TSO(1),SIE(1),SIEO(1),CHI(1),CHIO(1)
     A,VAP(1),VAPO(1),LIQ(1),LIQO(1)
     3    ,TYMF(25),FN(25),TYMT1(25),T1N(25),TYMT2(25),T2N(25),
     4    COFBA(25),COFBB(25),COFBC(25),COFTA(25),COFTB(25),COFTC(25),
     5    COFRA(25),COFRB(25),COFRC(25),COFLA(25),COFLB(25),COFLC(25),
     6    OFOBTA(25),OFOBTB(25),OFOBTC(25),
     7    OFOBRA(25),OFOBRB(25),OFOBRC(25),TAU(10),USL(32),USLOB(20),
     8    USROB(20),USTOB(20),USBOB(20)
     9,COFBD(25),COFBE(25),COFTD(25),COFTE(25),COFTF(25),COFBF(25),
     *COFRD(25),COFRE(25),COFLD(25),COFLE(25),COFRF(25),COFLF(25),
     AOFOBTD(25),OFOBTE(25),OFOBRD(25),OFOBRE(25),
     B  OFOBTF(25),OFOBRF(25),
     CTYMT3(25),TYMT4(25),TYMT5(25),T3N(25),T4N(25),T5N(25),
     *  IICFR(1),IICFL(1),IICFT(1),IICFB(1)
     *    ,ZERO1(1165),ZERO2(608),ZERO3(16),ZERO4(3)
      DIMENSION ZSIE(22),ZTQ(22),ZTS(22),ZVP(22),ZLQ(22),ZAP(22),WSP(22)
      DIMENSION TRSTRT(5),WZSIE(100),WZTQ(100),WZTS(100)
     A,WZVP(100),WZLQ(100),WZAP(100),WWSP(100)
      COMMON/VRCOM/A(14000)
      COMMON/RGB/RLAMB,CHII,GAMX,NRSTRT,TRSTRT,ZSIE,ZTQ,ZTS,WZSIE,WZTQ,
     AWZTS,NPROF,WZVP,WZLQ,ZVP,ZLQ,GAML,GAMV,VAP1,LIQI
     B,WSP,WWSP,BKGND,DWNDS
      COMMON /VRCON/ ALP,ALPO,ALX,ALZ,BO,BETA,BUFL,CFI(9),CFS(9),CYL,
     1    DT,DX,DZ,EMG,EPS,ERF,FSLIP,GAM,GAM1,GX,GZ,HDX,HDZ,I,I1,I2,I2K2,
     2    IBP1,IBP2,IBR,IDATIN,IDIAG,IKP2,IOBS,IRSTRT,ITAPW,ITER,IVDI,
     3    IVDO,K,K1,K2,K2NC,KBP1,KBP2,KBR,KNC,KWB,KWL,KWR,KWT,LABEL(20),
     4    LPR,MODEL,NCYC,NCYCB,NPRT,NU,NWPC,RDT,RDX,RDZ,RDZS
     *   ,RIBKB,ROI,TD,TFIN,TIMET,TIOSUM,TPL,TPLT,TPR,TPRT,TQI
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     5     ,TSI,TTD,TWTD,UI,WI,USR(32),UST(22),USB(22),USO(10)
     *     ,FFX3,FFY3
     6     ,AW,BW,CW,EPSB,UBLI,UBRI,WBBI,WBTI,WEPS,WOBI,NTPAS,TGAM,CSUBP,
     7     T0,SIEI,IDG,KDG,TI,MAT,RHOO,AT,TMU,TK,TYMF,FN,TYMT1,T1N,TYMT2,
     8     T2N,RPRAN,NRESEX,NFLOW,NT1,NT2,TSTEP,KDERBC,UOBI,COFBA,COFBB,
     9     COFBC,COFTA,COFTB,COFTC,COFRA,COFRB,COFRC,COFLA,COFLB,COFLC,
     *     OFOBTA,OFOBTB,OFOBTC,OFOBRA,OFOBRB,OFOBRC,TAU,NTAU,USL,
     1     USLOB,USROB,USTOB,USBOB,UMAX,WMAX
     *    ,CSUBPO,EPS0,RDXDZS,RLENGH ,TQJET,TSJET
      COMMON /FLMCON/ DROU,DROUO,IPRFM
      COMMON /VRMAT3/ AI,BI,CI,AR,BR,CR,AMU,BMU,CMU,AK,BK,CK,ACP,BCP,CCP
     1                   ,VMIN
        COMMON/PROP/SIGN
      COMMON/EXTRA/NT3,NT4,NT5,TYMT3,TYMT4,TYMT5,T3N,T4N,T5N,COFBD,
     1COFBE,COFBF,COFTD,COFTE,COFTF,COFRD,COFRE,COFRF,COFLD,COFLE,
     2COFLF,OFOBTD,OFOBTE,OFOBTF,OFOBRD,OFOBRE,OFOBRF,IRESET,
     *NCYCLS,TADD,NIV,IOBRAN
        COMMON/INDEX/NWPCL,K2NCL
        COMMON/LARGE/DIFFCO(2400)
      EQUIVALENCE (A(1),CF),(A(2),U),(A(3),W),(A(4),P),(A(5),TQ),
     1     (A(6),TS),(A(7),ER,CQ),(A(8),UO),(A(9),WO),(A(10),TQO),
     2     (A(11),TSO),(A(12),SIE),(A(13),SIEO),(A(14),RX),(A(15),RZ),
     3     (A(16),IICFR),(A(17),IICFL),(A(18),IICFT),(A(19),IICFB),
     A     (A(20),CHI),(A(21),CHIO),
     B     (A(22),VAP),(A(23),VAPO),(A(24),LIQ),(A(25),LIQO),
     4     (ZERO1(1),ALP),(ZERO2(1),NT3),(ZERO3(1),AI),(ZERO4(1),DROU)
C NOTE. END - END OF NON-EXECUTABLE STATEMENTS .
C
C NOTE. MESHMK IS RESPONSIBLE FOR GENERATION OF MESH SUBREGIONS .
C NOTE. READS,WRITES PRIMARY MESH INPUT DATA .
      READ(IVDI,1)    DX,DZ,GX,GZ,ALX,ALZ,CYL,BO,EPS,VMIN
      READ (IVDI,2) KWR,KWL,KWT,KWB,FSLIP,ALP,GAM,ALPO,GAM1,NU,TQJET,
     * TSJET
      READ(IVDI,7)    AW,BW,CW,WEPS,KDERBC,UBRI,UBLI,WBTI,WBBI
      READ(IVDI,8)    WOBI,UOBI,CSUBPO
      READ(IVDI,10)     TGAM,TO,TI,TSTEP,MAT,NRESEX
      READ(IVDI,1)    AI,BI,CI,AR,BR,CR,AMU,BMU,CMU
      READ (IVDI,1) AK,BK,CK,ACP,BCP,CCP,SIGN
      READ(IVDI,11) NFLOW,NT1,NT2,NT3,NT4,NT5,NTAU
      WRITE(IVDO,61) NFLOW,NT1,NT2,NT3,NT4,NT5,NTAU
       IF(NFLOW.GT.0) GO TO 190
       NIV=1.0
       NFLOW=-NFLOW
 190   CONTINUE
      READ(IVDI,12)    ( TYMF(I),FN(I),I=1,NFLOW )
      READ(IVDI,12)    ( TYMT1(I),T1N(I),I=1,NT1 )
      READ(IVDI,12)    ( TYMT2(I),T2N(I),I=1,NT2 )
       IF(NT3.EQ.0) GO TO 195
      READ(IVDI,12) (TYMT3(I),T3N(I),I=1,NT3)
       IF(NT4.EQ.0) GO TO 195
      READ(IVDI,12) (TYMT4(I),T4N(I),I=1,NT4)
       IF(NT5.EQ.0) GO TO 195
      READ(IVDI,12) (TYMT5(I),T5N(I),I=1,NT5)
 195   CONTINUE
      IF( NTAU.LT.1 ) GO TO 200
```

```
      READ(IVDI,12)   ( TAU(I),I=1,NTAU )
C NOTE. READ COEFFICIENTS A,B, AND C FOR THE BOTTOM EXTERIOR BOUNDARY .
 200  READ(IVDI,13) I,COFA,COFB,COFC,COFD,COFE,COFF
      IF( I.LT.1 ) GO TO 210
      COFBA(I)=COFA
      COFBB(I)=COFB
      COFBC(I)=COFC
      COFBD(I)=COFD
      COFBE(I)=COFE
      COFBF(I)=COFF
      WRITE(IVDO,64) I,COFBA(I),COFBB(I),COFBC(I),COFBD(I),COFBE(I),
     1  COFBF(I)
      GO TO 200
C NOTE. READ COEFFICIENTS A,B, AND C FOR THE   TOP  EXTERIOR BOUNDARY .
 210  READ(IVDI,13) I,COFA,COFB,COFC,COFD,COFE,COFF
      IF( I.LT.1 ) GO TO 220
      COFTA(I)=COFA
      COFTB(I)=COFB
      COFTC(I)=COFC
      COFTD(I)=COFD
      COFTE(I)=COFE
      COFTF(I)=COFF
      WRITE(IVDO,64) I,COFTA(I),COFTB(I),COFTC(I),COFTD(I),COFTE(I),
     1  COFTF(I)
      GO TO 210
C NOTE. READ COEFFICIENTS A,B, AND C FOR THE RIGHT  EXTERIOR BOUNDARY .
 220  READ(IVDI,13) I,COFA,COFB,COFC,COFD,COFE,COFF
      IF( I.LT.1 ) GO TO 230
      COFRA(I)=COFA
      COFRB(I)=COFB
      COFRC(I)=COFC
      COFRD(I)=COFD
      COFRE(I)=COFE
      COFRF(I)=COFF
      WRITE(IVDO,64) I,COFRA(I),COFRB(I),COFRC(I),COFRD(I),COFRE(I),
     1  COFRF(I)
      GO TO 220
C NOTE. READ COEFFICIENTS A,B, AND C FOR THE  LEFT  EXTERIOR BOUNDARY .
 230  READ(IVDI,13) I,COFA,COFB,COFC,COFD,COFE,COFF
      IF( I.LT.1 ) GO TO 240
      COFLA(I)=COFA
      COFLB(I)=COFB
      COFLC(I)=COFC
      COFLD(I)=COFD
      COFLE(I)=COFE
      COFLF(I)=COFF
      WRITE(IVDO,64) I,COFLA(I),COFLB(I),COFLC(I),COFLD(I),COFLE(I),
     1  COFLF(I)
      GO TO 230
C NOTE. READ COEFFICIENTS A,B, AND C FOR THE   TOP INTERIOR OBSTACLE .
 240  READ(IVDI,13) I,COFA,COFB,COFC,COFD,COFE,COFF
      IF( I.LT.1 ) GO TO 250
      OFOBTA(I)=COFA
      OFOBTB(I)=COFB
      OFOBTC(I)=COFC
```

```
      OFOBTD(I)=COFD
      OFOBTE(I)=COFE
      OFOBTF(I)=COFF
      WRITE(IVDO,64) I,OFOBTA(I),OFOBTB(I),OFOBTC(I),OFOBTD(I),
     1OFOBTE(I),OFOBTF(I)
      GO TO 240
C NOTE. READ COEFFICIENTS A,B, AND C FOR THE RIGHT INTERIOR OBSTACLE .
 250  READ(IVDI,13) I,COFA,COFB,COFC,COFD,COFE,COFF
      IF( I.LT.1 ) GO TO 310
      OFOBRA(I)=COFA
      OFOBRB(I)=COFB
      OFOBRC(I)=COFC
      OFOBRD(I)=COFD
       OFOBRE(I)=COFE
      OFOBRF(I)=COFF
      WRITE(IVDO,64) I,OFOBRA(I),OFOBRB(I),OFOBRC(I),OFOBRD(I),
     1OFOBRE(I),OFOBRF(I)
      GO TO 250
  310 READ(IVDI,14)   I,K,RXC,RZC
      WRITE(IVDO,65)  I,K,RXC,RZC
      IF( I.LT.1 ) GO TO 320
      IK=(K-1)*NWPC + (I-1)*K2NC + 1
      RX(IK)=RXC
      RZ(IK)=RZC
      GO TO 310
  320 CONTINUE
      WRITE(IVDO,50) DX,DZ,GX,GZ,ALX,ALZ,CYL,BO,EPS,VMIN
      WRITE (IVDO,51) KWR,KWL,KWT,KWB,FSLIP,ALP,GAM,ALPO,GAM1,NU,TQJET,
     * TSJET
      WRITE(IVDC,59) AW,BW,CW,WEPS,KDERBC,UBRI,UBLI,WBTI,WBBI
      WRITE(IVDC,58) WOBI,UOBI,CSU[illegible]O
      WRITE(IVDO,60)  TGAM,TO,TI,TSTEP,MAT,NRESEX
      WRITE(IVDC,52) AI,BI,CI,AR,BR,CR,AMU,BMU,CMU
      WRITE (IVDO,53) AK,BK,CK,ACP,BCP,CCP,SIGN
      WRITE(IVDC,61)  NFLOW,NT1,NT2,NTAU
      WRITE(IVDO,57)   ( TAU(I),I=1,NTAU )
      NMAX=AMAXO( NFLOW,NT1,NT2 )
      WRITE(IVDO,62)
      DO 319 I=1,NMAX
      WRITE(IVDO,63)  I,TYMF(I),FN(I),TYMT1(I),T1N(I),TYMT2(I),T2N(I)
  319 CONTINUE
       NMAX=AMAXO(NT3,NT4,NT5)
       DO 321 I=1,NMAX
      WRITE(IVDO,66) TYMT3(I),T3N(I),TYMT4(I),T4N(I),TYMT5(I),T5N(I)
 321   CONTINUE
C NOTE. GENERATION OF MESH CELL SIZES .
      RDX=1./DX
      RDZ=1./DZ
      HDX=.5*DX
      HDZ=.5*DZ
      RDZS=1./(DZ*DZ)
      BETA=.5*BO/(RDX*RDX + RDZ*RDZ)
      IF( KDERBC.GT.0 ) FSLIP=1.0
      IF( CYL.GT.1.E-6 ) KWL=1
      EPSB=4.*NU/AMIN1( DX,DZ )
```

```
      NTPAS=1
      IF( ALX.LT.EM6 .OR. ALZ.LT.EM6 ) NTPAS=2
      RDXDZS=1./( RDX*RDX + RDZ*RDZ )
      X1=FLOAT(IBR)*DX
      Z1=FLOAT(KBR)*DZ
      RLENGH=1./AMAX1( X1,Z1 )
      EPSO=EPS
      TR=TI + 459.7
C NOTE. CALCULATION OF SPECIFIC MATERIAL FOR SIE INITIAL AND RHOO .
      GO TO( 400,420,440,460 ),MAT
C NOTE. COMPUTATION FOR SODIUM MATERIAL .
  400 SIEII=0.38935*TR - 0.553E-4*TR**2 + 0.1137E-7*TR**3 - 29.02
      RHOII=59.566 - 7.9504E-3*TI - .2872E-6*TI**2 + 0.06035E-9*TI**3
      RHOO=59.566 - 7.9504E-3*TO - 0.2872E-6*TO**2 + 0.06035E-9*TO**3
      AT=397.17/TR + 1.0203
      TMU=(10.0**AT/3600.)/TR**0.4925
      NU=TMU/RHOII
      TK=0.015085 - 5.2167E-6*TI + 5.809E-10*TI**2
      CSUBP=0.38935 - 1.106E-4*TI + 0.3411E-7*TI**2
      RPRAN=TK/( CSUBP*TMU )
      GO TO 500
C NOTE. COMPUTATION FOR WATER MATERIAL .
  420 SIEII=1.0004*TI - 32.013
      RHOII=62.742 - 0.372E-2*TI - 0.44E-4*TI**2
      RHOO =62.742 - 0.372E-2*TO - 0.44E-4*TO**2
      BT=446.0/( TI+207.0 ) - 5.0
      TMU=1.622*10.**BT
      NU=TMU/RHOII
      TK=8.369E-5 + 2.368E-7*TI - 5.89E-10*TI**2
      CSUBP=1.0004
      RPRAN=TK/( CSUBP*TMU )
      GO TO 500
  440 SIEII=  AI*TI*TI +  BI*TI + CI
      RHOII=  AR*TI*TI +  BR*TI +  CR
      RHOO =  AR*TO*TO +  BR*TO +  CR
      TMU  = AMU*TI*TI + BMU*TI + CMU
      TK   =  AK*TI*TI +  BK*TI +  CK
      CSUBP= ACP*TI*TI + BCP*TI + CCP
      NU=TMU/RHOII
      RPRAN=TK/( CSUBP*TMU )
      GO TO 500
  460  CONTINUE
      NU=TMU/RHOII
      RPRAN=TK/( CSUBP*TMU )
C NOTE. NL=NUMBER OF LEFT MOST CELL , NR=NUMBER OF RIGHT MOST CELL ,
C NOTE. GENERATION OF INTERIOR MESH CELLS ,I.E. FLUID AND OBSTACLE .
  500 IF(IDATIN.GT.0.AND.IRESET.EQ.0) GO TO 590
      READ(IVDI,5)   NL,NR,NB,NT,ICELTY
      WRITE(IVDO,54) NL,NR,NB,NT,ICELTY
      IF( NL.EQ.0 ) GO TO 700
      READ(IVDI,6) SIEI,TQI,TSI,UI,WI,CHII,VAPI,LIQI
      WRITE(IVDO,55) SIEI,TQI,TSI,UI,WI,CHII,VAPI,LIQI
      I1=NL
      I2=NR
      K1=NB
```

```
      K2=NT
      KK=1 + (I1-2)*K2NC
      DO 589 I=I1,I2
      KK=KK + K2NC
      LWPC=(K1-2)*NWPC
      DO 579 K=K1,K2
      LWPC=LWPC + NWPC
      IK=KK + LWPC
      CF(IK)=ICELTY
C NOTE. FOR OBSTACLES WITH TAU FACTORS - SET SIEI = OBSTACLE TEMPERA -
C NOTE. TURE IN F DEGREES .
      SIE(IK)=SIEI
      IF( ICELTY.GE.30 .AND. NTAU.GT.0 ) P(IK)=SIEI
      TQ(IK)=TQI
      TS(IK)=TSI
      U(IK)=UI
      W(IK)=WI
      CHI(IK)=CHII
      VAP(IK)=VAPI
      LIQ(IK)=LIQI
      SIEO(IK)=SIE(IK)
      TQO(IK)=TQ(IK)
      TSO(IK)=TS(IK)
      UO(IK)=U(IK)
      WO(IK)=W(IK)
      CHIO(IK)=CHI(IK)
      VAPO(IK)=VAP(IK)
      LIQO(IK)=LIQ(IK)
  578 CONTINUE
  579 CONTINUE
  589 CONTINUE
      GO TO 500
 590  CONTINUE
C NOTE. GENERATION OF EXTERIOR BOUNDRY MESH CELLS .
  700 I1=1
      TSMAX=-1.0E+20
      TMAX=TSMAX
      WMAX=TMAX
      UMAX=WMAX
      TSMIN=+1.0E+20
      TMIN=TSMIN
      WMIN=TMIN
      UMIN=WMIN
      TQMAX=-1.E+20
      I2=IBP2
      K1=1
      K2=KBP2
      KK=1 + (I1-2)*K2NC
      DO 789 I=I1,I2
      KK=KK + K2NC
      LWPC=(K1-2)*NWPC
      DO 779 K=K1,K2
      LWPC=LWPC + NWPC
      IK=KK + LWPC
      UMAX=AMAX1( UMAX,U(IK) )
```

```
      WMAX=AMAX1( WMAX,W(IK) )
      UMIN=AMIN1( UMIN,U(IK) )
      WMIN=AMIN1( WMIN,W(IK) )
      TSMAX=AMAX1( TSMAX,TS(IK) )
      TSMIN=AMIN1( TSMIN,TS(IK) )
      TQMAX=AMAX1( TQMAX,TQ(IK) )
      CFC= CF(IK)
      IF( K.EQ.K1 .AND. CFC.LT.11 ) CF(IK)=10
      IF( K.EQ.K2 .AND. CFC.LT.11 ) CF(IK)=10
      IF( I.EQ.I1 .AND. CFC.LT.11 ) CF(IK)=10
      IF( I.EQ.I2 .AND. CFC.LT.11 ) CF(IK)=10
      IF( I.EQ.I1 .AND. K.EQ.K1 ) CF(IK)=2
      IF( I.EQ.I1 .AND. K.EQ.K2 ) CF(IK)=2
      IF( I.EQ.I2 .AND. K.EQ.K1 ) CF(IK)=2
      IF( I.EQ.I2 .AND. K.EQ.K2 ) CF(IK)=2
      IF( CFC.LT.20 .OR. IOBS.EQ.0 ) GO TO 770
C NOTE. FLAGS CELLS SURRONDING THE OBSTACLE CELL.
      CFR=CF(IK+K2NC)
      CFL=CF(IK-K2NC)
      CFT=CF(IK+NWPC)
      CFB=CF(IK-NWPC)
      IICFR(IK)=1
      IICFL(IK)=1
      IICFT(IK)=1
      IICFB(IK)=1
      IF (CFR.NE.1) IICFR(IK)=0
      IF (CFL.NE.1) IICFL(IK)=0
      IF (CFT.NE.1) IICFT(IK)=0
      IF (CFB.NE.1) IICFB(IK)=0
770   CONTINUE
  779 CONTINUE
  789 CONTINUE
      RETURN
C ***** FORMATS ***** FORMATS ***** FORMATS ***** .
    1 FORMAT(10F8.3)
    2 FORMAT (4I2,8F8.3)
    5 FORMAT(4I5,I2)
   6  FORMAT(8F8.3)
    7 FORMAT(4F8.3,I2,4F8.3)
    8 FORMAT(3F8.3)
   10 FORMAT(4F8.3,2I2)
 11   FORMAT(7X,I3,5(5X,I3),7X,I3)
   12 FORMAT(8F8.3)
 13   FORMAT(3X,I3,2X,6F8.3)
   14 FORMAT(2(3X,I3),2(5X,F8.3))
   50 FORMAT(1H ,5X,3HDX=,1PE12.5/6X,3HDZ=,E12.5/6X,3HGX=,E12.5/
     1 6X,3HGZ=,E12.5/5X,4HALX=,E12.5/5X,4HALZ=,E12.5/5X,4HCYL=,E12.5/
     2 6X,3HB0=,E12.5/5X,4HEPS=,E12.5/4X,5HVMIN=,E12.5)
   51 FORMAT(1H ,4X,4HKWR=,I2/5X,4HKWL=,I2/5X,4HKWT=,I2/5X,4HKWB=,I2/
     1 3X,6HFSLIP=,1PE12.5/5X,4HALP=,E12.5/5X,4HGAM=,E12.5/4X,5HALPO=,
     2E12.5/4X,5HGAM1=,E12.5/6X,3HNU=,E12.5/3X,6HTQJET=,E12.5/3X,
     36HTSJET=,E12.5)
   52 FORMAT(1H ,5X,3HAI=,1PE12.5/6X,3HBI=,E12.5/6X,3HCI=,E12.5/
     1 6X,3HAR=,E12.5/6X,3HBR=,E12.5/6X,3HCR=,E12.5/5X,4HAMU=,E12.5/
     2 5X,4HBMU=,E12.5/5X,4HCMU=,E12.5)
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   53 FORMAT(1H ,5X,3HAK=,1PE12.5/6X,3HBK=,E12.5/6X,3HCK=,E12.5/5X,        PLU10460
     14HACP=,E12.5/5X,4HBCP=,E12.5/,5X,4HCCP=,E12.5/5X,5HSIGN=,E12.5)     PLU10470
   54 FORMAT(1H ,3HNL ,I5,3HNR ,I5,3HNB ,I5,3HNT ,I5,8HICELTYP ,I2)        PLU10480
   55 FORMAT(1H ,3X,5HSIEI=,1PE12.5/5X,4HTQI=,E12.5/5X,4HTSI=,E12.5/      PLU10490
     16X,3HUI=,E12.5/6X,3HWI=,E12.5/5X,4HCHI=,E12.5/5X,4HVAP=,E12.5/5X,4PLU10500
     2HLIQ=,E12.5)                                                        PLU10510
   57 FORMAT(1H ,20H TAU FOR OBSTACLES =,7(2X,1PE12.5))                   PLU10520
   58 FORMAT(1H ,3X,5HWOBI=,1PE12.5/4X,5HUOBI=,E12.5/1X,8HCSUBPOB=,       PLU10530
     1 E12.5)                                                             PLU10540
   59 FORMAT(1H ,5X,3HAW=,1PE12.5/6X,3HBW=,E12.5/6X,3HCW=,E12.5/          PLU10550
     1 4X,5HWEPS=,E12.5/2X,7HKDERPC=,I2/4X,5HUBRI=,E12.5/4X,5HUBLI=,      PLU10560
     2 E12.5/4X,5HWBTI=,E12.5/4X,5HWBBI=,E12.5)                           PLU10570
   60 FORMAT(1H ,3X,5HTGAM=,1PE12.5/6X,3HT0=,E12.5/6X,3HTI=,E12.5/        PLU10580
     1 3X,6HTSTEP=,E12.5/5X,4HMAT=,I2/1X,8HNRESEXP=,I2)                   PLU10590
61    FORMAT(1H ,7H NFLOW ,I3,5H NT1 ,I3,5H NT2 ,I3,5H NT3 ,I3,5H NT4 ,   PLU10600
     1  I3,5H NT5 ,I3,6H NTAU ,I3)                                        PLU10610
   62 FORMAT(1H ,3X,1HI,9X,4HTYMF,12X,2HFN,11X,5HTYMT1,11X,3HT1N,11X,     PLU10620
     1 5HTYMT2,11X,3HT2N)                                                 PLU10630
   63 FORMAT(1H ,2X,I3,2X,6(2X,1PE11.4,2X))                               PLU10640
64    FORMAT(1H ,3H I ,I3,2X,6F8.3)                                        PLU10650
   65 FORMAT(1H ,3H I ,I3,3H K ,I3,5H RXC ,F8.3,5H RZC ,F8.3)             PLU10660
66    FORMAT(1H ,///,22X,6(2X,1PE11.4,2X))                                 PLU10670
      END                                                                 PLU10680
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      SUBROUTINE VM
      INTEGER BUFL,CF,CF1,CFB,CFC,CFI,CFL,CFR,CFS,CFT,CQF,ERF,TD,VNTP,
     1   VTP
      REAL NU,LIQ,LIQO,LIQI,LOUT
      REAL LIQL,LIQR,LIQT,LIQB,LIQC,LIQCO
      DIMENSION EFRAC(5),RLAM(5),ELAM(5)
      DIMENSION CF(1),CQ(1),QCON(1),P(1),RX(1),RZ(1),TQ(1),TS(1),U(1),
     1   W(1),ER(1),FFX3(102),FFY3(102),PBTIM(2),UO(1),WO(1),TQO(1),
     2   TSO(1),SIE(1),SIEO(1),CHI(1),CHIO(1)
     A,VAP(1),VAPO(1),LIQ(1),LIQO(1)
     3   ,TYMF(25),FN(25),TYMT1(25),T1N(25),TYMT2(25),T2N(25),
     4   COFBA(25),COFBB(25),COFBC(25),COFTA(25),COFTB(25),COFTC(25),
     5   COFRA(25),COFRB(25),COFRC(25),COFLA(25),COFLB(25),COFLC(25),
     6   OFOBTA(25),OFOBTB(25),OFOBTC(25),
     7   OFOBRA(25),OFOBRB(25),OFOBRC(25),TAU(10),USL(32),USLOB(20),
     8   USROB(20),USTOB(20),USBOB(20)
     9,COFBD(25),COFBE(25),COFTD(25),COFTE(25),COFTF(25),COFBF(25),
     *COFRD(25),COFRE(25),COFLD(25),COFLE(25),COFRF(25),COFLF(25),
     AOFOBTD(25),OFOBTE(25),OFOBRD(25),OFOBRE(25),
     B  OFOBTF(25),OFOBRF(25),
     CTYMT3(25),TYMT4(25),TYMT5(25),T3N(25),T4N(25),T5N(25),
     *  IICFR(1),IICFL(1),IICFT(1),IICFB(1)
     *   ,ZERO1(1165),ZERO2(608),ZERO3(16),ZERO4(3)
      DIMENSION ZSIE(22),ZTQ(22),ZTS(22),ZVP(22),ZLQ(22),ZAP(22),WSP(22)
      DIMENSION TRSTRT(5),WZSIE(100),WZTQ(100),WZTS(100)
     A,WZVP(100),WZLQ(100),WZAP(100),WWSP(100)
      COMMON/VRCOM/A(14000)
      COMMON/HAMZA/ZAP
      COMMON/RGB/RLAMB,CHII,GAMX,NRSTRT,TRSTRT,ZSIE,ZTQ,ZTS,WZSIE,WZTQ,
     AWZTS,NPROF,WZVP,WZLQ,ZVP,ZLQ,GAML,GAMV,VAPI,LIQI
     B,WSP,WWSP,BKGND,DWNDS
      COMMON /VRCON/ ALP,ALPO,ALX,ALZ,BO,BETA,BUFL,CFI(9),CFS(9),CYL,
     1   DT,DX,DZ,EM6,EPS,ERF,FSLIP,GAM,GAM1,GX,GZ,HDX,HDZ,I,I1,I2,I2K2,
     2   IBP1,IBP2,IBR,IDATIN,IDIAG,IKP2,IOBS,IRSTRT,ITAPW,ITER,IVDI,
     3   IVDO,K,K1,K2,K2NC,KBP1,KBP2,KBR,KNC,KWB,KWL,KWR,KWT,LABEL(20),
     4   LPR,MODEL,NCYC,NCYCB,NPRT,NU,NWPC,RDT,RDX,RDZ,RDZS
     *  ,RIBKB,ROI,TD,TFIN,TIMET,TIOSUM,TPL,TPLT,TPR,TPRT,TQI
     5   ,TSI,TTD,TWTD,UI,WI,USR(32),UST(22),USB(22),USO(10)
     *   ,FFX3,FFY3
     6   ,AW,BW,CW,EPSB,UBLI,UBRI,WBBI,WBTI,WEPS,WOBI,NTPAS,TGAM,CSUBP,
     7   TO,SIEI,IDG,KDG,TI,MAT,RHOO,AT,TMU,TK,TYMF,FN,TYMT1,T1N,TYMT2,
     8   T2N,RPRAN,NRESEX,NFLOW,NT1,NT2,TSTEP,KDERBC,UOBI,COFBA,COFBB,
     9   COFBC,COFTA,COFTB,COFTC,COFRA,COFRB,COFRC,COFLA,COFLB,COFLC,
     *   OFOBTA,OFOBTB,OFOBTC,OFOBRA,OFOBRB,OFOBRC,TAU,NTAU,USL,
     1   USLOB,USROB,USTOB,USBOB,UMAX,WMAX
     *  ,CSUBPO,EPSO,RDXDZS,RLENGH ,TQJET,TSJET
      COMMON /FLMCON/ DROU,DROUO,IPRFM
      COMMON /VRMAT3/ AI,BI,CI,AR,BR,CR,AMU,BMU,CMU,AK,BK,CK,ACP,BCP,CCP
     1                ,VMIN
       COMMON/PROP/SIGN
      COMMON/EXTRA/NT3,NT4,NT5,TYMT3,TYMT4,TYMT5,T3N,T4N,T5N,COFBD,
     1COFBE,COFBF,COFTD,COFTE,COFTF,COFRD,COFRE,COFRF,COFLD,COFLE,
     2COFLF,OFOBTD,OFOBTE,OFOBTF,OFOBRD,OFOBRE,OFOBRF,IRESET,
     *NCYCLS,TADD,NIV,IOBRAN
       COMMON/INDEX/NWPCL,K2NCL
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      COMMON/LARGE/DIFFCO(2400)                                          VM 00560
      EQUIVALENCE (A(1),CF),(A(2),U),(A(3),W),(A(4),P),(A(5),TQ),       VM 00570
     1   (A(6),TS),(A(7),ER,CQ),(A(8),UO),(A(9),WO),(A(10),TQO),        VM 00580
     2   (A(11),TSO),(A(12),SIE),(A(13),SIEO),(A(14),RX),(A(15),RZ),    VM 00590
     3   (A(16),IICFR),(A(17),IICFL),(A(18),IICFT),(A(19),IICFB),       VM 00600
     A   (A(20),CHI),(A(21),CHIO),                                      VM 00610
     B   (A(22),VAP),(A(23),VAPO),(A(24),LIQ),(A(25),LIQO),             VM 00620
     4   (ZERO1(1),ALP),(ZERO2(1),NT3),(ZERO3(1),AI),(ZERO4(1),DROU)    VM 00630
C NOTE. END - END OF NON-EXECUTABLE STATEMENTS .                          VM 00640
C NOTE. VM IS RESPONSIBLE FOR CALCULATION OF BOUNDARY CONDITIONS          VM 00650
C NOTE. AND EQUATIONS .                                                   VM 00660
      NRSTRT=1                                                           VM 00670
      READ(IVDI,57) GAMX,NCHAN,WMOLX,GAMV,GAML,BKGND,DWNDS               VM 00680
   57 FORMAT(F8.3,I8,5F8.3)                                              VM 00690
      WRITE(IVDO,58) GAMX,NCHAN,WMOLX,GAMV,GAML,BKGND                    VM 00700
   58 FORMAT(10H   GAMX =   ,F8.4,I5,' DECAY CHANNELS    MOLEC WT = ',F8.3/VM 00710
     110H   GAMV =   ,F8.4/10H   GAML =   ,F8.4/10H   BKGND = ,E8.4)    VM 00720
      WRITE(IVDO,64)                                                     VM 00730
   64 FORMAT(54H   DECAY CHANNEL     LAMBDA (1/SEC)   ENERGY (MEV) FRACT.) VM 00740
      READ(IVDI,65) (RLAM(J),ELAM(J),EFRAC(J),J=1,NCHAN)                 VM 00750
   65 FORMAT(3F8.3)                                                      VM 00760
      WRITE(IVDO,66) (J,RLAM(J),ELAM(J),EFRAC(J),J=1,NCHAN)              VM 00770
   66 FORMAT(8X,I1,13X,F8.5,7X,F8.5,3X,F6.4)                             VM 00780
      RLAMB=0.0                                                          VM 00790
      SER=0.0                                                            VM 00800
      DO 98 J=1,NCHAN                                                    VM 00810
      SER=SER+RLAM(J)*ELAM(J)*EFRAC(J)                                   VM 00820
   98 RLAMB=RLAMB+RLAM(J)                                                VM 00830
      WRITE(IVDO,67) RLAMB,SER                                           VM 00840
   67 FORMAT(' RLAMB = ',E10.5,' SPEC. ENERGY RELEASE = ',E10.5)         VM 00850
      READ(IVDI,62) NPROF,(TRSTRT(L),L=1,5)                              VM 00860
   62 FORMAT(I8,5F8.3)                                                   VM 00870
      READ(IVDI,56) (WZSIE(K),WZTQ(K),WZTS(K),WZVP(K),WZLQ(K),WZAP(K),WWVM 00880
     ASP(K),K=1,NPROF)                                                   VM 00890
   56 FORMAT(2F8.3,F8.1,F9.6,3F8.3,23X)                                  VM 00900
      WRITE(IVDO,59)(WZSIE(K),WZTQ(K),WZTS(K),WZVP(K),WZLQ(K),WZAP(K),WWVM 00910
     ASP(K),K=1,NPROF)                                                   VM 00920
   59 FORMAT(' ',2F10.3,F13.3,F10.6,3F10.3)                              VM 00930
C  TRANSFER OF PROFILES BEFORE ANY RESTART CASES                          VM 00940
      DO 99 K=2,KBP1                                                     VM 00950
      WSP(K)=WWSP(K-1)                                                   VM 00960
      ZAP(K)=WZAP(K-1)                                                   VM 00970
      ZVP(K)=WZVP(K-1)                                                   VM 00980
      ZLQ(K)=WZLQ(K-1)                                                   VM 00990
      ZSIE(K)=WZSIE(K-1)                                                 VM 01000
      ZTQ(K)=WZTQ(K-1)                                                   VM 01010
   99 ZTS(K)=WZTS(K-1)                                                   VM 01020
      WSP(1)=0.0                                                         VM 01030
      ZAP(1)=0.0                                                         VM 01040
      ZVP(1)=ZVP(2)                                                      VM 01050
      ZLQ(1)=ZLQ(2)                                                      VM 01060
      ZSIE(1)=ZSIE(2)                                                    VM 01070
      ZTQ(1)=ZTQ(2)                                                      VM 01080
      ZTS(1)=ZTS(2)                                                      VM 01090
      WSP(KBP2)=0.0                                                      VM 01100
```

```
      ZAP(KBP2)=0.0
      ZVP(KBP2)=ZVP(KBP1)
      ZLQ(KBP2)=ZLQ(KBP1)
      ZSIE(KBP2)=ZSIE(KBP1)
      ZTQ(KBP2)=ZTQ(KBP1)
      ZTS(KBP2)=ZTS(KBP1)
C NOTE. CALCULATION OF CONSTANTS AND PREASSIGNED BRANCHES .
      IF( IRSTRT.EQ.0 ) GO TO 100
      CALL VRPRT
      IF( IDROU.GT.0 ) DROU=DROU0*AMIN1(DX,DZ)/AMAX1(UMAX,WMAX,EM6)
      IF( IPRFM.GT.0 ) CALL VRFLM
      IRSTRT=0
  100 ITER=0
      ICALI=1
      X1=AMAX1( UMAX,WMAX )
      VELOLD=X1
      EPS=EPS0*X1*RLENGH
      IF( X1.LT.VMIN ) EPS=EPS0*VMIN*RLENGH
      IF( EPS0.LT.EM6 ) EPS=ABS( EPS0 )
      ASSIGN 2000 TO KBC
C NOTE. COMPUTATION OF FNTAU,T1NTAU AND T2NTAU .
      FNTAU=SI( TYMF,FN,TIMET,NFLOW )
      T1NTAU=SI( TYMT1,T1N,TIMET,NT1 )
       IF(NT2.EQ.0) GO TO 107
      T2NTAU=SI( TYMT2,T2N,TIMET,NT2 )
       IF(NT3.EQ.0) GO TO 107
      T3NTAU=SI(TYMT3,T3N,TIMET,NT3)
       IF(NT4.EQ.0) GO TO 107
      T4NTAU=SI(TYMT4,T4N,TIMET,NT4)
       IF(NT5.EQ.0) GO TO 107
      T5NTAU=SI(TYMT5,T5N,TIMET,NT5)
 107   CONTINUE
C NOTE. ZERO OUT THE CQ(IK) ARRAY FOR TAU FACTORS IN SIE EQUATION .
      I1=2
      I2=IBP1
      K1=2
      K2=KBP1
      KK=1
      ITAUCN=0
      DO 109 I=I1,I2
      KK=KK + K2NC
      LWPC=0
      DO 109 K=K1,K2
      LWPC=LWPC + NWPC
      IK=KK + LWPC
      CQ(IK)=0.0
  109 CONTINUE
      IF( NCYCB.LT.NCYC ) GO TO 1000
C NOTE. CALCULATION OF DIAGNOSTIC CONSTANTS .
      ASSIGN 12500 TO KDAGTU
C NOTE. PREASSIGN BRANCHES FOR RESISTANCE EQUATIONS , I.E. RX AND RZ .
      RXC=0.0
      RZC=0.0
      ASSIGN 2300 TO KRXRZ
      IF( NWPC.GT.13 ) ASSIGN 2250 TO KRXRZ
```

```
C NOTE. PREASSIGN BRANCHES FOR PLANE - CYL=0.0 - OR CYLINDRICAL
C NOTE. - CYL=1.0 - COORDINATES .
      FCU=0.0
      FCW=0.0
      RL=1.0
      RC=RL
      RR=RC
      DR=DX
      RRL=1.0
      RRC=RRL
      RRR=RRC
      RRRC=1.0
      RRP=RRRC
      RDR=RDX
      RDRS=1./( DR*DR )
      RDRM=RDR
      RDRP=RDRM
      RDZM=RDZ
      RDZP=RDZM
      ASSIGN 2400 TO KCLU
      ASSIGN 2500 TO KCLW
      ASSIGN 2220 TO KRU
      IF( CYL.LT.EM6 ) GO TO 120
      ASSIGN 2370 TO KCLU
      ASSIGN 2470 TO KCLW
      ASSIGN 2215 TO KRU
  120 ASSIGN 13000 TO KDIAG
      IF( IDIAG.LT.1 ) GO TO 200
      ASSIGN 12200 TO KDIAG
      IF( IDIAG.GT.1 ) ASSIGN 12500 TO KDIAG
  200 TSUM=0.0
      TIOSUM=0.0
C
C NOTE. COMPUTATION OF BOUNDARY CONDITIONS .
C
1000  LWPC=1 - NWPC
      IF( KDERBC.LT.1 ) GO TO 1100
C
C NOTE. COMPUTATION OF RIGHT AND LEFT BOUNDARY CONDITIONS .
1100  LWPC=1 - NWPC
      I1=1
      I2=IBP2
      K1=1
      K2=KBP2
      NDERR=0
      NDERL=0
      NCOFR=0
      NCOFL=0
      DO 1289 K=K1,K2
      LWPC=LWPC+NWPC
      IMK=LWPC
      CFL= CF(IMK)
      ICFL=CFL
      IPK=IMK + IKP2
      IPPK=IPK + K2NC
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```
      IMKT=IMK + K2NC
      IPKT=IPK
      CFR= CF(IPPK)
      ICFR=CFR
      IF( CFL.NE.2 ) GO TO 1105
      IF( K.EQ.K2 ) GO TO 1103
      IMKT=IMK + K2NC + NWPC
      IPKT=IPK + NWPC
      CFL= CF(IMK+NWPC)
      CFR= CF(IPPK+NWPC)
      GO TO 1105
1103  IMKT=IMK + K2NC - NWPC
      IPKT=IPK - NWPC
      CFL= CF(IMK-NWPC)
      CFR= CF(IPPK-NWPC)
 1105 W(IMK)=W(IMKT)
      W(IPPK)=W(IPK)
C NOTE. COMPUTATION OF REFLECTIVE BOUNDARY CONDITIONS ON TQ AND TS .
      SIE(IMK)=SIE(IMKT)
      SIE(IPPK)=ZSIE(K)
      TQ(IMK)=TQ(IMKT)
      TQ(IPPK)=ZTQ(K)
      TS(IMK)=TS(IMKT)
      TS(IPPK)=ZTS(K)
      CHI(IMK)=CHI(IMKT)
      CHI(IPPK)=0.0
      IF(U(IPKT).GT.0.0) CHI(IPPK)=CHI(IPKT)
      VAP(IMK)=VAP(IMKT)
      VAP(IPPK)=ZVP(K)
      LIQ(IMK)=LIQ(IMKT)
      LIQ(IPPK)=ZLQ(K)
      GO TO ( 1120,1130,1140,1150 ),KWL
C NOTE. COMPUTATION OF RIGID  LEFT  WALL BOUNDARY CONDITION .
1120  U(IMK)=0.0
      GO TO 1180
C NOTE. COMPUTATION OF CONTINUATIVE  LEFT  WALL BOUNDARY CONDITION .
1130  IF( ITER.GT.0 ) GO TO 1180
      U(IMK)=U(IMK+K2NC)
      W(IMK) = -W(IMK+K2NC)
      W(IMK-NWPC) = -W(IMK+K2NC-NWPC)
      GO TO 1180
C NOTE. COMPUTATION OF PERIODIC  LEFT  WALL BOUNDARY CONDITION .
1140  U(IMK)=U(IPK)
      GO TO 1180
C NOTE. VARIABLE BOUNDARY OPTION AT LEFT WALL .
1150  NCFL=CFL - 9
      GO TO ( 1152,1130,1155,1160 ),NCFL
C NOTE. RIGID BOUNDARY SECTION AT LEFT WALL .
1152  NRIGID=KDERBC + 1
      GO TO( 1120,1153 ),NRIGID
C NOTE. DERIVED BOUNDARY CONDITION AT LEFT WALL .
1153  WC=W(IMKT)
      IF( K.EQ.1 ) GO TO 1120
      IF (K.GE.(KBR+1)) GO TO 1120
      ICF1=CF(IMKT)
```

```
      IF (ICF1.GE.30) GO TO 1120
      QC=TQ( IMKT)
      SC=TS( IMKT)
      NDERL=NDERL + 1
      WSA=USL(NDERL)
      QW=5.*WSA*WSA
      W(IMK) = -WC
      SW = WSA * WSA * HDX/WC
      TQ(IMK)=2.*QW - QC
      TS(IMK)=2.*SW - SC
      GO TO 1120
C NOTE. CONSTANT INFLOW AT LEFT WALL .
1155  U(IMK)=UBLI
      GO TO 1180
C NOTE. VARIABLE OR FUNCTIONAL INFLOW AT LEFT WALL .
1160  IF( ICFL.EQ.2 ) GO TO 1180
      NCOFL=NCOFL + 1
      TI=COFLB(NCOFL)*T1NTAU + COFLC(NCOFL)*T2NTAU
     1+COFLD(NCOFL)*T3NTAU+COFLE(NCOFL)*T4NTAU+COFLF(NCOFL)*T5NTAU
      ASSIGN 1162 TO KIROBC
      SIEX=SIE(IMKT)
      GO TO 1500
1162  AREAK=3.14159265*FLOAT(2*K-3)*DZ*DZ
      IF( CYL.LT.1.0 ) AREAK=DZ
      FLK=COFLA(NCOFL)*FNTAU
      UBAR=FLK/RHOII
      U(IMK)=UBAR/AREAK
       IF(NIV.EQ.1) U(IMK)=FLK
      SIE(IMK)=SIEII
      TS(IMK)=TS(IPK)
      TQ(IMK)=TQ(IPK)
1180  GO TO( 1220,1230,1240,1250 ),KWR
C NOTE. COMPUTATION OF RIGID RIGHT  WALL BOUNDARY CONDITION .
1220  U(IPK)=0.0
      GO TO 1280
C NOTE. COMPUTATION OF CONTINUATIVE RIGHT  WALL BOUNDARY CONDITION .
1230  IF( ITER.GT.0 ) GO TO 1280
      U(IPPK)=U(IPK-K2NC)
      W(IPPK-NWPC)=W(IPK-NWPC)
      GO TO 1280
C NOTE. COMPUTATION OF PERIODIC RIGHT  WALL BOUNDARY CONDITION .
1240  U(IPPK)=U(IMK+K2NC)
      W(IPPK)=W(IMK+K2NC)
      GO TO 1280
C NOTE. VARIABLE BOUNDARY OPTION AT RIGHT WALL .
1250  NCFR=CFR - 9
      GO TO( 1252,1230,1255,1260 ),NCFR
C NOTE. RIGID BOUNDARY SECTION AT RIGHT WALL .
1252  NRIGID=KDERBC + 1
      GO TO( 1220,1253 ),NRIGID
C NOTE. DERIVED BOUNDARY CONDITION AT RIGHT WALL .
1253  WC=W(IPKT)
      IF (K.GE.(KBR+1)) GO TO 1220
      IF( K.EQ.1 ) GO TO 1220
      ICF2=CF(IPKT)
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      IF (ICF2.GE.30) GO TO 1220
      QC=TQ(IPKT)
      SC=TS(IPKT)
      NDERR=NDERR + 1
      WSA=USR(NDERR)
      QW=5.*WSA*WSA
 1256 SW = WSA * WSA * HDX/WC
      W(IPPK) = -WC
      TQ(IPPK)=2.*QW-QC
      TS(IPPK)=2.*SW-SC
      GO TO 1220
C NOTE. CONSTANT INFLOW AT RIGHT WALL .
1255  U(IPK)=UBRI
      GO TO 1280
C NOTE. VARIABLE OR FUNCTIONAL INFLOW AT RIGHT WALL .
1260  IF( ICFR.EQ.2 ) GO TO 1280
      NCOFR=NCOFR + 1
      TI=COFRB(NCOFR)*T1NTAU + COFRC(NCOFR)*T2NTAU
     1+COFRD(NCOFR)*T3NTAU+COFRE(NCOFR)*T4NTAU+COFRF(NCOFR)*T5NTAU
      ASSIGN 1262 TO KIROBC
      SIEX=SIE(IPKT)
      GO TO 1500
 1262 AREAK = 3.14159265 * 2 * IBR * DR * DZ
      IF( CYL.LT.1.0 ) AREAK=DZ
      FLK=COFRA(NCOFR)*FNTAU
      UBAR=FLK/RHOII
      U(IPK)=UBAR/AREAK
       IF(NIV.EQ.1) U(IPK)=FLK
       SIEC=SIE(IPKT)
       SIEW=SIEII
       SIE(IPPK)=(2*SIEW+(ALX-1.0)*SIEC)/(1.0+ALX)
      QC = TQ(IPKT)
      QW = TQJET * U(IPK)*U(IPK)
      SC = TS(IPKT)
      SW = TSJET * U(IPK) * DZ
       SW=ABS(SW)
       QW=AMAX1(QW,1.0E-5)
       SW=AMAX1(SW,NU)
       TQ(IPPK)=(2*QW+(ALX-1.0)*QC)/(1.0+ALX)
       TS(IPPK)=(2*SW+(ALX-1.0)*SC)/(1.0+ALX)
1280  CONTINUE
1289  CONTINUE
C NOTE. COMPUTATION OF TOP AND BOTTOM BOUNDARY CONDITIONS .
      NDERB=0
      NDERT=0
      NCOFB=0
      NCOFT=0
      KK=1 - K2NC
      DO 1489 I=I1,I2
      KK=KK+K2NC
      IKM=KK
      CFB= CF(IKM)
      ICFB=CFB
      IKP=IKM + KNC
      IKPP=IKP + NWPC
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      CFT= CF(IKPP)
      ICFT=CFT
      IKMT=IKM + NWPC
      IKPT=IKP
      IF( CFB.NE.2 ) GO TO 1305
      IF( I.EQ.I2 ) GO TO 1303
      IKMT=IKM + K2NC + NWPC
      IKPT=IKP + K2NC
      CFB= CF(IKM+K2NC)
      CFT= CF(IKPP+K2NC)
      GO TO 1305
1303  IKMT=IKM - K2NC + NWPC
      IKPT=IKP - K2NC
      CFB= CF(IKM-K2NC)
      CFT= CF(IKPP-K2NC)
 1305 U(IKM)=-U(IKMT)
      U(IKPP)=U(IKP)
C NOTE. COMPUTATION OF REFLECTIVE BOUNDARY CONDITIONS ON TQ AND TS .
      SIE(IKM)=SIE(IKMT)
      SIE(IKPP)=SIE(IKPT)
      TQ(IKM)=TQ(IKMT)
      TQ(IKPP)=TQ(IKPT)
      TS(IKM)=TS(IKMT)
      TS(IKPP)=TS(IKPT)
      CHI(IKM)=CHI(IKMT)
      CHI(IKPP)=0.0
      IF(W(IKPT).GT.0.0) CHI(IKPP)=CHI(IKPT)
      VAP(IKM)=VAP(IKMT)
      VAP(IKPP)=VAP(IKPT)
      LIQ(IKM)=LIQ(IKMT)
      LIQ(IKPP)=LIQ(IKPT)
      GO TO( 1320,1330,1340,1350 ),KWT
C NOTE. COMPUTATION OF RIGID  TOP   WALL BOUNDARY CONDITION .
1320  W(IKP)=0.0
      GO TO 1380
C NOTE. COMPUTATION OF CONTINUATIVE  TOP   WALL BOUNDARY CONDITION .
1330  IF( ITER.GT.0 ) GO TO 1380
      W(IKPP)=W(IKP-NWPC)
      U(IKPP-K2NC)=U(IKP-K2NC)
      GO TO 1380
C NOTE. COMPUTATION OF PERIODIC  TOP   WALL BOUNDARY CONDITION .
1340  W(IKPP)=W(IKM+NWPC)
      U(IKPP)=U(IKM+NWPC)
      GO TO 1380
C NOTE. VARIABLE BOUNDARY OPTION AT TOP WALL .
1350  NCFT=CFT - 9
      GO TO( 1352,1330,1355,1360 ),NCFT
C NOTE. RIGID BOUNDARY SECTION AT TOP WALL .
1352  NRIGID=KDERBC + 1
      GO TO( 1320,1353 ),NRIGID
C NOTE. DERIVED BOUNDARY CONDITION AT TOP WALL .
1353  UCT=U(IKP)
      IF( I.EQ.1 ) GO TO 1320
      IF (I.GE.(IBR+1)) GO TO 1320
      ICF3=CF(IKP)
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      IF (ICF3.GE.30) GO TO 1320
      QCT=TQ(IKP)
      SCT=TS(IKP)
      NDERT=NDERT + 1
      USAT=UST(NDERT)
      QWT=5.*USAT*USAT
 1356 SWT = USAT * USAT * HDZ /UCT
      U(IKPP) = -UCT
      TQ(IKPP)=2.*QWT - QCT
      TS(IKPP)=2.*SWT - SCT
      GO TO 1320
C.NOTE  CONSTANT INFLOW AT TOP WALL .
1355  W(IKP)=WBTI
      GO TO 1380
C NOTE. VARIABLE OR FUNCTIONAL INFLOW AT TOP WALL .
1360  IF( ICFT.EQ.2 ) GO TO 1380
      NCOFT=NCOFT + 1
      TI=COFTB(NCOFT)*T1NTAU + COFTC(NCOFT)*T2NTAU
     1+COFTD(NCOFT)*T3NTAU+COFTE(NCOFT)*T4NTAU+COFTF(NCOFT)*T5NTAU
      ASSIGN 1362 TO KIROBC
      SIEX=SIE(IKPT)
      GO TO 1500
1362  AREAI=3.14159265*FLOAT(2*I-3)*DR*DR
      IF( CYL.LT.1.0 ) AREAI=DX
      FLI=COFTA(NCOFT)*FNTAU
      WBAR=FLI/RHOII
      W(IKP)=WBAR/AREAI
       IF(NIV.EQ.1) W(IKP)=FLI
       SIEC=SIE(IKP )
       SIEW=SIFII
       SIE(IKPP)=(2*SIEW+(ALZ-1.0)*SIEC)/(1.0+ALZ)
      QCT=TQ(IKP)
      QWT=TQJET*W(IKP)*W(IKP)
      SCT=TS(IKP)
      SWT=TSJET*W(IKP)*DR
       SWT=ABS(SWT)
       QWT=AMAX1(QWT,1.0E-5)
       SWT=AMAX1(SWT,NU)
       TQ(IKPP)=(2*QWT+(ALZ-1.0)*QCT)/(1.0+ALZ)
       TS(IKPP)=(2*SWT+(ALZ-1.0)*SCT)/(1.0+ALZ)
1380  GO TO( 1420,1430,1440,1450 ),KWB
C NOTE. COMPUTATION OF RIGID BOTTOM WALL BOUNDARY CONDITION .
1420  W(IKM)=0.0
      GO TO 1480
C NOTE. COMPUTATION OF CONTINUATIVE BOTTOM WALL BOUNDARY CONDITION .
1430  IF( ITER.GT.0 ) GO TO 1480
      W(IKM)=W(IKM+NWPC)
      U(IKM)=-U(IKM+NWPC)
      U(IKM-K2NC)=-U(IKM+NWPC-K2NC)
      GO TO 1480
C NOTE. COMPUTATION OF PERIODIC BOTTOM WALL BOUNDARY CONDITION .
1440  W(IKM)=W(IKP)
      GO TO 1480
C NOTE. VARIABLE BOUNDARY OPTION AT BOTTOM WALL .
1450  NCFB=CFB - 9
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      GO TO( 1452,1430,1455,1460 ),NCFB
C NOTE. RIGID BOUNDARY SECTION AT BOTTOM WALL .
1452  NRIGID=KDERBC + 1
      GO TO( 1420,1453 ),NRIGID
C NOTE. DERIVED BOUNDARY CONDITION AT BOTTOM .
1453  IK=IKM + NWPC
      IF( I.EQ.1 ) GO TO 1420
      IF (I.GE.(IBR+1)) GO TO 1420
      ICF4=CF(IK)
      IF (ICF4.GE.30) GO TO 1420
      UCB=U(IK)
      QCB=TQ(IK)
      SCB=TS(IK)
      NDERB=NDERB + 1
      USAB=USB(NDERB)
      QWB=5.*USAB*USAB
 1456 SWB=USAB*USAB*HDZ/UCB
      U(IKM)=-UCB
      TQ(IKM)=2.*QWB - QCB
      TS(IKM)=2.*SWB - SCB
      GO TO 1420
C NOTE. CONSTANT INFLOW AT BOTTOM WALL .
1455  W(IKM)=WBBI
      GO TO 1480
C NOTE. VARIABLE OR FUNCTIONAL INFLOW AT BOTTOM WALL .
1460  IF( ICFB.EQ.2 ) GO TO 1480
      NCOFB=NCOFB + 1
      TI=COFBB(NCOFB)*T1NTAU + COFBC(NCOFB)*T2NTAU
     1+COFBD(NCOFB)*T3NTAU+COFBE(NCOFB)*T4NTAU+COFBF(NCOFB)*T5NTAU
      ASSIGN 1462 TO KIROBC
      SIEX=SIE(IKMT)
      GO TO 1500
1462  AREAI=3.14159265*FLOAT(2*I-3)*DR*DR
      IF( CYL.LT.1 0 ) AREAI=DX
      FLI=COFBA(NCOFB)*FNTAU
      WBAR=FLI/RHOII
      W(IKM)=WBAR/AREAI
       IF(NIV.EQ.1) W(IKM)=FLI
       SIEC=SIE(IK  )
       SIEW=SIEII
       SIE(IKM )=(2*SIEW+(ALZ-1.0)*SIEC)/(1.0+ALZ)
      QCB=TQ(IK)
      QWB=TQJET*W(IKM)*W(IKM)
      SCB=TS(IK)
      SWB=TSJET*W(IKM)*DR
       QWB=AMAX1(QWB,1.0E-5)
       SWB=AMAX1(SWB,NU)
       TQ(IKM )=(2*QWB+(ALZ-1.0)*QCB)/(1.0+ALZ)
       TS(IKM )=(2*SWB+(ALZ-1.0)*SCB)/(1.0+ALZ)
1480  CONTINUE
1489  CONTINUE
      GO TO 1700
C NOTE. COMPUTATION OF SIE AND RHO FOR VARIABLE OR FUNCTIONAL INFLOW
C NOTE. AT A BOUNDARY WALL .
1500  TR=TI + 459.7
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      GO TO( 1510,1520,1530,1540 ),MAT
C NOTE. COMPUTATION FOR SODIUM MATERIAL .
1510  SIEII=0.38935*TR - 0.553E-4*TR*TR + 0.1137E-7*TR*TR*TR-29.02
      RHOII=59.566 - 7.9504E-3*TI - .2872E-6*TI*TI + 0.06035E-9*TI*TI*TI
      AT=397.17/TR + 1.0203
      TMU=(10.0**AT/3600.)/TR**0.4925
      TK=0.015085 - 5.2167E-6*TI + 5.809E-10*TI*TI
      TEMP =-385.27 + 2.6602*SIEX + 5.9894E-04*SIEX*SIEX +
     1      1.5575E-06*SIEX*SIEX*SIEX-2.9048E-09*SIEX*SIEX*SIEX*SIEX+
     2      1.15427E-12*SIEX*SIEX*SIEX*SIEX*SIEX
      IF( ICSUBP.GT.0 ) TI=TEMP
      CSUBP=0.38935 - 1.106E-4*TI + 0.3411E-7*TI*TI
      GO TO 1550
C NOTE. COMPUTATION FOR WATER MATERIAL .
1520  SIEII=1.0004*TI - 32.013
      RHOII=62.742 - 0.372E-2*TI - 0.44E-4*TI*TI
      BT=446.0/( TI+207.0 ) - 5.0
      TMU=1.622*10.**BT
      TK=8.369E-5 + 2.368E-7*TI - 5.89E-10*TI*TI
      TEMP=0.9996*SIEX + 32.0002
      CSUBP=1.0004
      GO TO 1550
1530  SIEII=  AI*TI*TI +  BI*TI + CI
      RHOII=  AR*TI*TI +  BR*TI +  CR
      TMU  = AMU*TI*TI + BMU*TI + CMU
      TK   =  AK*TI*TI +  BK*TI +  CK
      CIT=CI-SIEX
      TEMP=SI( AI,BI,CIT,-1 )
      CSUBP= ACP*TI*TI + BCP*TI + CCP
      GO TO 1550
1540  CONTINUE
1550  NU=TMU/RHOII
      RPRAN=TK/( CSUBP*TMU )
      GO TO KIROBC,( 1162,1262,1362,1462,1605,1615,1625,1635,1736,1756 )
C
C NOTE. COMPUTATION OF THE TAU FACTOR FOR USE IN THE SIE EQUATION .
C
C NOTE. FLUID CELL TO THE   LEFT OF THE IK OBSTACLE .
1600  ICSUBP=0
      IF( ITAUCN.GT.1 .OR. NTAU.LT.1 ) GO TO 1714
      ASSIGN 1605 TO KIROBC
      SIEX=SIE(IMK)
      ICSUBP=1
      GO TO 1500
1605  NTAU=CFC - 29
      RTAU=1./TAU(NTAU)
      P(IK)=1./(1.+DT*RTAU)*( P(IK) + DT*RTAU*TEMP )
      CQ(IMK)=CSUBPO*RTAU*( TEMP-P(IK) )
      ICSUBP=0
      GO TO 1714
C NOTE. FLUID CELL TO THE BOTTOM OF THE IK OBSTACLE .
1610  ICSUBP=0
      IF( ITAUCN.GT.1 .OR. NTAU.LT.1 ) GO TO 1724
      ASSIGN 1615 TO KIROBC
      SIEX=SIE(IKM)
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      ICSUBP=1
      GO TO 1500
1615  NTAU=CFC - 29
      RTAU=1./TAU(NTAU)
      P(IK)=1./(1.+DT*RTAU)*( P(IK) + DT*RTAU*TEMP )
      CQ(IKM)=CSUBPO*RTAU*( TEMP-P(IK) )
      ICSUBP=0
      GO TO 1724
C NOTE. FLUID CELL TO THE   TOP  OF THE IK OBSTACLE .
1620  ICSUBP=0
      IF( ITAUCN.GT.1 .OR. NTAU.LT.1 ) GO TO 1744
      ASSIGN 1625 TO KIROBC
      SIEX=SIE(IKP)
      ICSUBP=1
      GO TO 1500
1625  NTAU=CFC - 29
      RTAU=1./TAU(NTAU)
      CQ(IKP)=CSUBPO*RTAU*(TI-P(IK))
      ICSUBP=0
      GO TO 1744
C NOTE. FLUID CELL TO THE  RIGHT OF THE IK OBSTACLE .
1630  ICSUBP=0
      IF( ITAUCN.GT.1 .OR. NTAU.LT.1 ) GO TO 1764
      ASSIGN 1635 TO KIROBC
      SIEX=SIE(IPK)
      ICSUBP=1
      GO TO 1500
1635  NTAU=CFC - 29
      RTAU=1./TAU(NTAU)
      P(IK)=1./(1.+DT*RTAU)*( P(IK) + DT*RTAU*TEMP )
      CQ(IPK)=CSUBPO*RTAU*( TEMP-P(IK) )
      ICSUBP=0
      GO TO 1764
C
C NOTE. COMPUTATUON OF OBSTACLE SUBREGIONS BOUNDARY CONDITIONS .
C
1700  KK=1
      ITAUCN=ITAUCN + 1
      I1=2
      I2=IBP1
      K1=2
      K2=KBP1
      IF( IOBS.EQ.0 ) GO TO 1990
      NDERR=0
      NDERL=0
      NDERB=0
      NDERT=0
      NCOFT=0
      NCOFR=0
      DO 1789 I=I1,I2
      KK=KK + K2NC
      LWPC=0
      DO 1779 K=K1,K2
      LWPC=LWPC + NWPC
      IK=KK + LWPC
```

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      IMK=IK - K2NC
      IKM=IK - NWPC
      IKP=IK + NWPC
      IPK=IK + K2NC
      ICFC=CF(IK)
      CFC=ICFC
      IF( CFC.EQ.1 ) GO TO 1778
      CFT=IICFT(IK)+1
      CFB=IICFB(IK)+1
      CFR=IICFR(IK)+1
      CFL=IICFL(IK)+1
      IF( CFT.GT.1 ) GO TO 1710
      IF( CFB.GT.1 ) GO TO 1710
      IF( CFR.GT.1 ) GO TO 1710
      IF( CFL.GT.1 ) GO TO 1710
      U(IK)=0.0
      U(IMK)=0.0
      W(IK)=0.0
      W(IKM)=0.0
      TS(IK)=0.0
      TQ(IK)=0.0
      SIE(IK)=0.0
      GO TO 1770
C NOTE. OBSTACLE BOUNDARY CONDITION AT THE  LEFT  FACE .
1710  GO TO( 1720,1600 ),CFL
C NOTE. NON-FLUID CELL TO THE  LEFT  OF THE IK OBSTACLE .
1712  U(IMK)=0.0
      GO TO 1720
C NOTE. FLUID CELL TO THE   LEFT OF THE IK OBSTACLE .
1714  U(IMK)=0.0
      NRIGID=KDERBC + 1
      GO TO ( 1715,1716 ),NRIGID
C NOTE. RIGID BOUNDARY AT THE   LEFT FACE .
1715  W(IK)=FSLIP*W(IMK)
      SIE(IK)=SIE(IMK)
      TQ(IK)=TQ(IMK)
      TS(IK)=TS(IMK)
      GO TO 1720
C NOTE. DERIVED BOUNDARY CONDITION AT THE  LEFT  FACE .
1716  WC=W(IMK)
      QC=TQ(IMK)
      SC=TS(IMK)
      NDERL=NDERL + 1
      WSA=USLOB(NDERL)
      QW=5.*WSA*WSA
      SW=WSA*WSA*HDX/WC
      W(IK)=-WC
      TQ(IK)=2.*QW - QC
      TS(IK)=2.*SW - SC
      GO TO 1712
C NOTE. OBSTACLE BOUNDARY CONDITION AT THE BOTTOM FACE .
1720  GO TO( 1730,1610 ),CFB
C NOTE. NON-FLUID CELL TO THE BOTTOM OF THE IK OBSTACLE .
1722  W(IKM)=0.0
      GO TO 1730
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C NOTE. FLUID CELL TO THE BOTTOM OF THE IK OBSTACLE .
1724  W(IKM)=0.0
      NRIGID=KDERBC + 1
      GO TO( 1725,1726 ),NRIGID
C NOTE. RIGID BOUNDARY AT THE BOTTOM FACE .
1725  U(IK)=FSLIP*U(IKM)
      SIE(IK)=SIE(IKM)
      TQ(IK)=TQ(IKM)
      TS(IK)=TS(IKM)
      GO TO 1730
C NOTE. DERIVED BOUNDARY CONDITION AT THE BOTTOM FACE .
1726  UCT=U( IKM)
      QCT=TQ(IKM)
      SCT=TS(IKM)
      NDERB=NDERB + 1
      USAT=USBOB(NDERB)
      QWT=5.*USAT*USAT
      SWT=USAT*USAT*HDZ/UCT
      U(IK)=-UCT
      TQ(IK)=2.*QWT - QCT
      TS(IK)=2.*SWT - SCT
      GO TO 1722
C NOTE. OBSTACLE BOUNDARY CONDITION AT THE  TOP  FACE .
1730  IF( CFC.GE.30 ) GO TO 1740
C NOTE. VARIABLE BOUNDARY OPTION AT THE  TOP  FACE .
      NCFT=CFC - 21
      GO TO( 1732,1734,1740,1740,1740 ),NCFT
C NOTE. CONSTANT INFLOW AT THE  TOP  FACE .
1732  W(IK)=WOBI
      GO TO 1745
C NOTE. VARIABLE OR FUNCTIONAL INFLOW AT THE TOP FACE .
1734  NCOFT=NCOFT + 1
      TI=OFOBTB(NCOFT)*T1NTAU + OFOBTC(NCOFT)*T2NTAU
     1+OFOBTD(NCOFT)*T3NTAU+OFOBTE(NCOFT)*T4NTAU+OFOBTF(NCOFT)*T5NTAU
      ASSIGN 1736 TO KIROBC
      SIEX=SIE(IKP)
      GO TO 1500
1736  AREAI=3.14159265*FLOAT(2*I-3)*DR*DR
      IF( CYL.LT.1.0 ) AREAI=DX
      FLI=OFOBTA(NCOFT)*FNTAU
      WBAR=FLI/RHOII
      W(IK)=WBAR/AREAI
       IF(NIV.EQ.1) W(IK)=FLI
       SIEC=SIE(IKP )
       SIEW=SIEII
       SIE(IK  )=(2*SIEW+(ALZ-1.0)*SIEC)/(1.0+ALZ)
      QCT = TQ(IKP)
      QWT = TQJET * W(IK)*W(IK)
      SCT = TS(IKP)
      SWT = TSJET * W(IK) * DR
       QWT=AMAX1(QWT,1.0E-5)
       SWT=AMAX1(SWT,NU)
       TQ(IK  )=(2*QWT+(ALZ-1.0)*QCT)/(1.0+ALZ)
       TS(IK  )=(2*SWT+(ALZ-1.0)*SCT)/(1.0+ALZ)
      U(IK)=FSLIP*U(IKP)
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      GO TO 1750
C NOTE. OBSTACLE BOUNDARY CONDITION AT THE   TOP  FACE .
1740  GO TO( 1750,1620 ),CFT
C NOTE. NON-FLUID CELL TO THE   TOP  OF THE IK OBSTACLE .
1742  W(IK)=0.0
      GO TO 1750
C NOTE. FLUID CELL TO THE   TOP  OF THE IK OBSTACLE .
1744  W(IK)=0.0
      NRIGID=KDERBC + 1
      GO TO( 1745,1746 ),NRIGID
C NOTE. RIGID BOUNDARY AT THE   TOP  FACE .
 1745 U(IK)=-U(IKP)
      SIE(IK)=SIE(IKP)
      TQ(IK)=TQ(IKP)
      TS(IK)=TS(IKP)
      GO TO 1750
C NOTE. DERIVED BOUNDARY CONDITION AT THE   TOP  FACE .
1746  UCT=U(IKP)
      QCT=TQ(IKP)
      SCT=TS(IKP)
      NDERT=NDERT + 1
      USAT=USTOB(NDERT)
      QWT=5.*USAT*USAT
      SWT = USAT * USAT * HDZ/UCT
      U(IK) = -UCT
      TQ(IK)=2.*QWT - QCT
      TS(IK)=2.*SWT - SCT
      GO TO 1742
C NOTE. OBSTACLE BOUNDARY CONDITION AT THE  RIGHT FACE .
1750  IF( CFC.GE.30 ) GO TO 1760
C NOTE. VARIABLE BOUNDARY OPTION AT THE RIGHT FACE .
      NCFR=CFC - 21
      GO TO( 1776,1776,1776,1752,1754 ),NCFR
C NOTE. CONSTANT INFLOW AT THE RIGHT FACE .
1752  U(IK)=UOBI
      GO TO 1765
C NOTE. VARIABLE OR FUNCTIONAL INFLOW AT THE RIGHT FACE .
1754  NCOFR=NCOFR + 1
      TI=OFOBRB(NCOFR)*T1NTAU + OFOBRC(NCOFR)*T2NTAU
     1+OFOBRD(NCOFR)*T3NTAU+OFOBRE(NCOFR)*T4NTAU+OFOBRF(NCOFR)*T5NTAU
      ASSIGN 1756 TO KIROBC
      SIEX=SIE(IPK)
      GO TO 1500
 1756 AREAK = 3.14159265 * 2*(I-1) * DR * DZ
      IF( CYL.LT.1.0 ) AREAK=DZ
      FLK=OFOBRA(NCOFR)*FNTAU
      UBAR=FLK/RHOII
      U(IK)=UBAR/AREAK
       IF(NIV.EQ.1) U(IK)=FLK
       SIEC=SIE(IPK )
       SIEW=SIEII
       SIE(IK  )=(2*SIEW+(ALX-1.0)*SIEC)/(1.0+ALX)
      QC = TQ(IPK)
      QW = TQJET * U(IK)*U(IK)
      SC = TS(IPK)
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```
      SW = TSJET * U(IK) * DZ
       QW=AMAX1(QW,1.0E-5)
       SW=AMAX1(SW,NU)
       TQ(IK   )=(2*QW+(ALX-1.0)*QC)/(1.0+ALX)
       TS(IK   )=(2*SW+(ALX-1.0)*SC)/(1.0+ALX)
      W(IK)=FSLIP*W(IPK)
      GO TO 1770
C NOTE. OBSTACLE BOUNDARY CONDITION AT THE  RIGHT FACE .
1760  GO TO( 1770,1630 ),CFR
C NOTE. NON-FLUID CELL TO THE  RIGHT OF THE IK OBSTACLE .
1762  U(IK)=0.0
      GO TO 1770
C NOTE. FLUID CELL TO THE  RIGHT OF THE IK OBSTACLE .
1764  U(IK)=0.0
      NRIGID=KDERBC + 1
      GO TO( 1765,1766 ),NRIGID
C NOTE. RIGID BOUNDARY AT THE  RIGHT FACE .
1765  W(IK)=FSLIP*W(IPK)
      SIE(IK)=SIE(IPK)
      TQ(IK)=TQ(IPK)
      TS(IK)=TS(IPK)
      GO TO 1770
C NOTE. DERIVED BOUNDARY CONDITION AT THE  RIGHT FACE .
1766  WC=W(IPK)
      QC=TQ(IPK)
      SC=TS(IPK)
      NDERR=NDERR + 1
      WSA=USROB(NDERR)
      QW=5.*WSA*WSA
      SW = WSA * WSA * HDX/WC
      W(IK) = -WC
      TQ(IK)=2.*QW - QC
      TS(IK)=2.*SW - SC
      GO TO 1762
1770  IF( CFT.EQ.2 .AND. CFC.GE.30 ) W(IK)=0.0
1776  IF( CFR.EQ.2 .AND. CFC.LT.25 ) U(IK)=0.0
1778  CONTINUE
1779  CONTINUE
1789  CONTINUE
1990  GO TO KBC,( 2000,2990,4100,5000,5060 )
C
C NOTE. CHECKS FOR INITIAL CYCLES PRINTS ,I.E. NPRT=0 NO PRINT,
C NOTE. NPRT=1 CYCLE 0 PRINT AND NPRT=2 CYCLE 0,1 PRINTS .
C
2000  IF( NCYC.LT.NPRT ) GO TO 2010
      GO TO 2030
2010  CALL VRPRT
      IF( IPRFM.GT.0 ) CALL VRFLM
C NOTE. CALL TO THE VARIABLE RESISTANCE SUBROUTINE .
C NOTE. BEGIN THE N PASS PHASE OF THE TILDE EQUATION SECTION .
2030  DO 2999 NTE=1,NTPAS
      IF( NWPC.GT.11 ) CALL VREQ
C
C NOTE. U AND W TILDE VELOCITY EQUATIONS SECTION .
C
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C NOTE. TRANSFERS VELOCITIES TO STORAGE ARRAY( AT TIME=N ) .
      K1=1
      K2=KBP2
      LWPC=1 - NWPC
      DO 2109 K=K1,K2
      LWPC=LWPC+NWPC
      IK=LWPC
      IKS=I2K2 + IK
      SIE(IKS)=SIE(IK)
      U(IKS)=U(IK)
      W(IKS)=W(IK)
      TQ(IKS)=TQ(IK)
      TS(IKS)=TS(IK)
      CHI(IKS)=CHI(IK)
      VAP(IKS)=VAP(IK)
      LIQ(IKS)=LIQ(IK)
 2109 CONTINUE
      I1=2
      I2=IBP1
      K1=2
      K2=KBP2
      KK=0
      KKL = 0
      DO 2989 I=I1,I2
      KK=KK+K2NC
      KKL = KKL + K2NCL
      LWPCL = 1
      LWPC=1
      IKMS=I2K2 + 1
      SIE(1)=SIE(IKMS)
      U(1)=U(IKMS)
      W(1)=W(IKMS)
      TQ(1)=TQ(IKMS)
      TS(1)=TS(IKMS)
      CHI(1)=CHI(IKMS)
      VAP(1)=VAP(IKMS)
      LIQ(1)=LIQ(IKMS)
      SIE(IKMS)=SIE(KK+1)
      U(IKMS)=U(KK+1)
      W(IKMS)=W(KK+1)
      TQ(IKMS)=TQ(KK+1)
      TS(IKMS)=TS(KK+1)
      CHI(IKMS)=CHI(KK+1)
      VAP(IKMS)=VAP(KK+1)
      LIQ(IKMS)=LIQ(KK+1)
      GO TO KRU,( 2215,2220 )
C NOTE. COMPUTATION OF RADIUS CONSTANTS IN THE I DIRECTION .
 2215 RR=FLOAT(I-1)*DX
      RC=RR-HDX
      RL=RR-DX
      RRR=1./RR
      RRC=1./RC
      RRC1=RR + HDX
      RRRC=1./RRC1
      RRP=RR + DR
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```
2220  DO 2979 K=K1,K2
C NOTE. COMPUTATION OF CELL INDICES .
      LWPC=LWPC+NWPC
      IK=KK + LWPC
      LWPCL = LWPCL + NWPCL
      IKL = KKL + LWPCL
      DCR = DIFFCO(IKL)
      DCT = DIFFCO(IKL+1)
      DCL = DIFFCO(IKL+2)
      DCB = DIFFCO(IKL+3)
C NOTE. BYPASS OBSTACLE CELLS .
      CFC=CF(IK)
      IPK=IK + K2NC
      IKP=IK + NWPC
      IMKS=I2K2 + LWPC
      IKMS=IMKS - NWPC
      UR=U(IPK)
      UC=U(IK)
      UL=U(IMKS)
      WT=W(IKP)
      WC=W(IK)
      WB=W(IKMS)
      PC=P(IK)
      PR=P(IPK)
      PT=P(IKP)
      SIEC=SIE(IK)
      SIER=SIE(IPK)
      SIET=SIE(IKP)
      SIEL=SIE(IMKS)
      SIEB=SIE(IKMS)
      SIECO=SIEO(IK)
      UCO=UO(IK)
      WCO=WO(IK)
C NOTE. COMPUTATION OF TQ AND TS CONSTANTS .
      TQC=TQ(IK)
      TQR=TQ(IPK)
      TQT=TQ(IKP)
      TQL=TQ(IMKS)
      TQB=TQ(IKMS)
      TQCO=TQO(IK)
      TSC=TS(IK)
      TSR=TS(IPK)
      TST=TS(IKP)
      TSL=TS(IMKS)
      TSB=TS(IKMS)
      TSCO=TSO(IK)
      CHIC=CHI(IK)
      CHIR=CHI(IPK)
      CHIT=CHI(IKP)
      CHIL=CHI(IMKS)
      CHIB=CHI(IKMS)
      CHICO=CHIO(IK)
      VAPC=VAP(IK)
      VAPR=VAP(IPK)
      VAPT=VAP(IKP)
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```
      VAPL=VAP(IMKS)
      VAPB=VAP(IKMS)
      VAPCO=VAPO(IK)
      LIQC=LIQ(IK)
      LIQR=LIQ(IPK)
      LIQT=LIQ(IKP)
      LIQL=LIQ(IMKS)
      LIQB=LIQ(IKMS)
      LIQCO=LIQO(IK)
      IF( CFC.NE.1 ) GO TO 2700
      TSTR=.25*( TSR + TSC + TST + TS(IKP+K2NC) )
      TSBR=.25*( TSR + TSC + TSB + TS(IPK-NWPC) )
      TSTL=.25*( TSL + TSC + TST + TS(IMKS+NWPC) )
      IF( ICALI.EQ.2 ) GO TO 2500
      GO TO KRXRZ,( 2250,2300 )
C NOTE. STORAGE OF SUBSCRIPTED RX(),RZ() TO CONSTANT RXC AND RZC .
2250  RXC=RX(IK)*ABS( UC )**NRESEX
      RZC=RZ(IK)*ABS( WC )**NRESEX
C NOTE. COMPUTATION OF U TILDE FLUXES .
2300  URA=.5*(UC+UR)
      URAA=ABS(URA)
      ULA=.5*(UL+UC)
      ULAA=ABS(ULA)
      FUX=.5*RDX*( URA*(UC+UR) + ALX*URAA*(UC-UR) - ULA*(UL+UC)
     1          -ALX*ULAA*(UL-UC) )
      WTA=.5*(WC+W(IPK))
      WTAA=ABS(WTA)
      WBA=.5*(WB+W(IPK-NWPC))
      WBAA=ABS(WBA)
      FUZ=.5*RDZ*( WTA*(UC+U(IKP)) + ALZ*WTAA*(UC-U(IKP))
     1          - WBA*(U(IKMS)+UC) - ALZ*WBAA*(U(IKMS)-UC) )
C NOTE. CALCULATION OF THE U TILDE DIFFUSION TERMS .
      DURR=RDRP*RRRC*TSR*( RRP*UR - RR*UC )
      DURL=RDR*RRC*TSC*( RR*UC - RL*UL )
      DUR=RDR*( DURR - DURL )
      DUZ=RDZ*( TSTR*(U(IKP)-UC)*RDZP - TSBR*(UC-U(IKMS))*RDZM )
      FUT=DUR + DUZ
      GO TO KCLU,( 2370,2400 )
C NOTE. COMPUTATION OF THE U TILDE CYLINDRICAL FLUX TERM .
2370  FCU=.5*RRR*( URA*URA + ULA*ULA + .5*ALX*URAA*(UC-UR)
     1             + .5*ALX*ULAA*(UL-UC) )
C NOTE. COMPUTATION OF W TILDE FLUXES .
2400  UTA=.5*(UC+U(IKP))
      UTAA=ABS(UTA)
      ULT=.5*(UL+U(IMKS+NWPC))
      ULTA=ABS(ULT)
      WTA=.5*( WC+WT )
      WTAA=ABS( WTA )
      WBA=.5*( WB+WC )
      WBAA=ABS( WBA )
      FWX=.5*RDX*( UTA*(WC+W(IPK)) + ALX*UTAA*(WC-W(IPK))
     1          - ULT*(W(IMKS)+WC) - ALX*ULTA*(W(IMKS)-WC) )
      FWZ=.5*RDZ*( WTA*(WC+WT) + ALZ*WTAA*(WC-WT)
     1          - WBA*(WB+WC) - ALZ*WBAA*(WB-WC) )
C NOTE. CALCULATION OF THE W TILDE DIFFUSION TERMS .
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      DWRR=RDRP*RR*TSTR*(W(IPK)-WC)
      DWRL=RDRM*RL*TSTL*(WC-W(IMKS))
      DWR=RRC*RDR*( DWRR - DWRL )
      DWZ=RDZP*( TST*(WT-WC)*RDZ - TSC*(WC-WB)*RDZ )
      FWT=DWR + DWZ
      GO TO KCLW,( 2470,2500 )
C NOTE. COMPUTATION OF THE W TILDE CYLINDRICAL FLUX TERM .
2470  FCW=.25*RRC*( UTA*(WC+W(IPK)) + ULT*(W(IMKS)+WC)
     1            + ALX*UTAA*(WC-W(IPK)) + ALX*ULTA*(W(IMKS)-WC) )
C NOTE. COMPUTATION  OF BOTH  Q AND SIGMA TURBULANCE QUANTITIES .
C  CALCULATION OF THE Q EQUATION BUOYANCY TERM
      BET=1./(459.7+T0)
      BUOYQ=TGAM*TSC*(TEMPT-TEMPC)*RDZ*GZ*BET
2500  TQRA=.5*(TQC+TQR)
      IF( ICALI.EQ.1 ) GO TO 2591
      TQLA=.5*(TQC+TQL)
      TQTA=.5*(TQC+TQT)
      TQBA=.5*(TQC+TQB)
      TSRA=.5*(TSC+TSR)
      TSLA=.5*(TSC+TSL)
      TSTA=.5*(TSC+TST)
      TSBA=.5*(TSC+TSB)
C NOTE. CALCULATION OF THE SIJ  TERM,I.E. THE SOURCE TERM .
      SIJ=RDRS*(UC-UL)**2 + RDZS*(WC-WB)**2 + .25*CYL*(RRC*(UC+UL))**2 +
     1    0.03125*( RDZ*( U(IKP)+U(IMKS+NWPC)-U(IKMS)-U(1) )
     2            + RDR*( W(IPK)+W(IPK-NWPC)-W(IMKS)-W(1) ) )**2
C NOTE. CALCULATION OF THE Q EQUATION CONVECTION TERMS .
      CQR=-.5*RRC*RDR*( RR*( UC*(TQC+TQR) + ALX*ABS(UC)*(TQC-TQR) )
     1                - RL*( UL*(TQL+TQC) + ALX*ABS(UL)*(TQL-TQC) ) )
      CQZ=-.5*RDZ*(WC*(TQC+TQT) + ALZ*ABS(WC)*(TQC-TQT)
     1           - WB*(TQB+TQC) - ALZ*ABS(WB)*(TQB-TQC) )
C NOTE. CALCULATION OF THE Q EQUATION DIFFUSION TERM .
      DQRR = RRC * RDR * (RR * TSRA * (TQR - TQC)) * DCR
      DQRL = RRC * RDR * (RL * TSLA * ( TQC - TQL)) * DCL
      DQR = RDR * ( DQRR - DQRL)
      DQZT = RDZ * ( TSTA * ( TQT - TQC )) * DCT
      DQZB = RDZ * ( TSBA * ( TQC - TQB )) * DCB
      DQZ = RDZ * ( DQZT - DQZB)
C NOTE. CALCULATION OF THE Q EQUATION DECAY TERM .
      DQ=4.*ALP*TQC/( TSC+1.E-20 )
C NOTE. CALCULATION OF THE NEW Q AT TIME N+1 .
      TQ(IK)=(1./(1.+DT*DQ))*( TQCO + DT*(CQR+CQZ+2.*TSC*SIJ +
     1                   BUOYQ+GAM*(DQR+DQZ)) )
C NOTE. COMPUTATION  OF SIGMA QUANTITIES .
C NOTE. CALCULATION OF THE SIGMA EQUATION CONVECTION TERMS .
      CSR=-.5*RRC*RDR*( RR*( UC*(TSC+TSR) + ALX*ABS(UC)*(TSC-TSR) )
     1                - RL*( UL*(TSL+TSC) + ALX*ABS(UL)*(TSL-TSC) ) )
      CSZ=-.5*RDZ*( WC*(TSC+TST) + ALZ*ABS(WC)*(TSC-TST)
     1            - WB*(TSB+TSC) - ALZ*ABS(WB)*(TSB-TSC) )
C NOTE. CALCULATION OF THE SIGMA EQUATION DIFFUSION TERM .
      IF( I.LT.I2 ) GO TO 2502
      IFLGS=0
      IFLGQ=0
      IF( TQR.LT.0.0 ) IFLGQ=1
      IF( TSR.LT.0.0 ) IFLGS=1
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      IFLG1=IFLGQ+IFLGS
      IF( IFLG1.EQ.2 ) TQR=-TQR
2502  IF( K.GT.K1  ) GO TO 2504
      IFLGS=0
      IFLGQ=0
      IF( TQB.LT.0.0 ) IFLGQ=1
      IF( TSB.LT.0.0 ) IFLGS=1
      IFLG1=IFLGQ + IFLGS
      IF( IFLG1.EQ.2 ) TQB=-TQB
2504  IF( K.LT.KBP1 ) GO TO 2506
      IFLGS=0
      IFLGQ=0
      IF( TQT.LT.0.0 ) IFLGQ=1
      IF( TST.LT.0.0 ) IFLGS=1
      IFLG1=IFLGQ + IFLGS
      IF( IFLG1.EQ.2 ) TQT=-TQT
2506  IF( I.GT.I1  ) GO TO 2508
      IFLGS=0
      IFLGQ=0
      IF( TQL.LT.0.0 ) IFLGQ=1
      IF( TSL.LT.0.0 ) IFLGS=1
      IFLG1=IFLGQ + IFLGS
      IF( IFLG1.EQ.2 ) TQL=-TQL
2508  CONTINUE
      DSRR = RRC * RDR * ( RR * TQRA * ( TQR/TSR - TQC/TSC )) * DCR
      DSRL = RRC * RDR * ( RL * TQLA * (TQC/TSC - TQL/TSL )) * DCL
      DSR = RDR * ( DSRR - DSRL)
      DSZT = RDZ * ( TQTA * ( TQT/TST - TQC/TSC)) * DCT
      DSZB = RDZ * ( TQBA * ( TQC/TSC - TQB/TSB )) * DCB
      DSZ = RDZ * ( DSZT - DSZB)
C CALCULATION OF THE SIGMA EQUATION BUOYANCY TERM
      BUOYS=BUOYQ*TSC/TQC
C
C NOTE.  IF-STATEMENT SELECTS TURBULENCE MODEL.  "MODEL"=0 FOR STANDARD
C        VARR K-SIGMA MODEL.  "MODEL"=1 FOR TEACH K-EPSILON MODEL.
C
      IF (MODEL) 2550,2550,2555
C
C NOTE.  VARR K-SIGMA TURBULENCE MODEL.
C
 2550 DIJ=GAM*TSC/TQC*( DQR+DQZ ) - GAM1*TSC*TSC*TSC/TQC**2*(DSR+DSZ)
      DS=4.*ALPO*TQC/(TSC+1.E-20)
C NOTE. CALCULATION OF THE NEW SIGMA AT N+1 .  (K-SIGMA MODEL)
      TS(IK)=(1./(1.+DT*DS))*( TSCO+DT*(CSR+CSZ+TSC*TSC/TQC*SIJ+DIJ+
     1   BUOYS) )
      GO TO 2560
C
C NOTE. CALCULATION OF EXTRA TERM NEEDED TO MAKE VARR AND TEACH-T TURB-
C       ULENCE MODELS EQUIVALENT.  N.B. THESE EQUATIONS CAN BE USED WITH
C       RECTANGULAR COORDINATES ONLY!!!
C
 2555 DSRKER=RDR * ( TQRA**4/TSRA**3 ) * ( TSR - TSC ) * DCR
      DSRKEL=RDR * ( TQLA**4/TSLA**3 ) * ( TSC - TSL ) * DCL
      DSRKEM=RDR * ( DSRKER - DSRKEL )
      DSZKET=RDZ * ( TQTA**4/TSTA**3 ) * ( TST - TSC )  * DCT
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```
      DSZKEB=RDZ * ( TQBA**4/TSBA**3 ) * ( TSC - TSB )  * DCB
      DSZKEM=RDZ * ( DSZKET - DSZKEB )
      DIJKEM=-.5 * GAM1 * ((TSC/TQC)**4) * ( DSRKEM + DSZKEM )
      DIJ=2.*GAM*TSC/TQC*(DQR+DQZ) - GAM1*TSC*TSC*TSC/TQC**2*(DSR+DSZ)
      DS=4.*ALPO*TQC/(TSC+1.E-20)
C NOTE.  CALCULATION OF THE NEW SIGMA AT N+1.  (K-EPSILON MODEL)
      SUMKEM= (TSCO+DT*(CSR+CSZ+TSC*TSC/TQC*1.12*SIJ+DIJ+DIJKEM+
     1   BUOYS))
      TS(IK)= (1./(1.+DT*DS))*SUMKEM
 2560 IF( TQ(IK).LT.1.E-5 ) TQ(IK)=1.E-5
C     DIJ=GAM*TSC/TQC*( DQR+DQZ ) - GAM1*TSC*TSC*TSC/TQC*TQC*(DSR+DSZ)
      DIJ=GAM*TSC/TQC*( DQR+DQZ ) - GAM1*TSC*TSC*TSC/TQC**2*(DSR+DSZ)
C     DS=4.*ALPO*TQC/( TSC+1.E-20 )
      DS=ALP*TQC/(TSC+1.E-20)
C NOTE. CALCULATION OF THE NEW SIGMA AT N+1 .
      TS(IK)=(1./(1.+DT*DS))*( TSCO+DT*(CSR+CSZ+TSC*TSC/TQC*SIJ+DIJ) )
      IF(TQ(IK).LT.ZTQ(K)) TQ(IK)=ZTQ(K)
      IF(TS(IK).LT.ZTS(K)) TS(IK)=ZTS(K)
C  CALCULATION OF TERMS IN THE VAP TRANSPORT EQUATION
      CVR=.5*RRC*RDR*( RR*( UC*(VAPC+VAPR) + ALX*ABS(UC)*(VAPC-VAPR) )
     1               - RL*( UL*(VAPL+VAPC) + ALX*ABS(UL)*(VAPL-VAPC) ) )
      CVZ=.5*RDZ*( WC*(VAPC+VAPT) + ALZ*ABS(WC)*(VAPC-VAPT)
     1            - WB*(VAPB+VAPC) - ALZ*ABS(WB)*(VAPB-VAPC) )
        DVRR=RDR*(RR*GAMV*TSRA*DCR*(VAPR-VAPC))
        DVRL=RDR*(RL*GAMV*TSLA*DCL*(VAPC-VAPL))
        DVR=RRC*RDR*(DVRR-DVRL)
        DVZT=RDZ*(GAMV*TSTA*DCT*(VAPT-VAPC))
        DVZB=RDZ*(GAMV*TSBA*DCB*(VAPC-VAPB))
        DVZ=RDZ*(DVZT-DVZB)
      VAP(IK)=VAPCO+DT*(-CVR-CVZ+DVR+DVZ)
C  CALCULATION OF TERMS IN THE LIQ TRANSPORT EQUATION
      CLR=.5*RRC*RDR*( RR*( UC*(LIQC+LIQR) + ALX*ABS(UC)*(LIQC-LIQR) )
     1               - RL*( UL*(LIQL+LIQC) + ALX*ABS(UL)*(LIQL-LIQC) ) )
      CLZ=.5*RDZ*( WC*(LIQC+LIQT) + ALZ*ABS(WC)*(LIQC-LIQT)
     1            - WB*(LIQB+LIQC) - ALZ*ABS(WB)*(LIQB-LIQC) )
        DLRR=RDR*(RR*GAML*TSRA*DCR*(LIQR-LIQC))
        DLRL=RDR*(RL*GAML*TSLA*DCL*(LIQC-LIQL))
        DLR=RRC*RDR*(DLRR-DLRL)
        DLZT=RDZ*(GAML*TSTA*DCT*(LIQT-LIQC))
        DLZB=RDZ*(GAML*TSBA*DCB*(LIQC-LIQB))
        DLZ=RDZ*(DLZT-DLZB)
      LIQ(IK)=LIQCO+DT*(-CLR-CLZ+DLR+DLZ)
C
C NOTE. COMPUTATION OF SPECIFIC INTERNAL ENERGY .
C
C NOTE. CALCULATION OF THE SIE EQUATION CONVECTION TERMS .
 2590 CIR=.5*RRC*RDR*( RR*( UC*(SIEC+SIER) + ALX*ABS(UC)*(SIEC-SIER) )
     1               - RL*( UL*(SIEL+SIEC) + ALX*ABS(UL)*(SIEL-SIEC) ) )
      CIZ=.5*RDZ*( WC*(SIEC+SIET) + ALZ*ABS(WC)*(SIEC-SIET)
     1            - WB*(SIEB+SIEC) - ALZ*ABS(WB)*(SIEB-SIEC) )
C NOTE. CALCULATION OF THE SIE EQUATION DIFFUSION TERMS .
      GAMT=TGAM
      IF( TSC.LE.NU ) GAMT=RPRAN
        DIRR=RDR*(RR*GAMT*TSRA*DCR*(SIER-SIEC))
        DIRL=RDR*(RL*GAMT*TSLA*DCL*(SIEC-SIEL))
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      DIR=RRC*RDR*(DIRR-DIRL)
      DIZT=RDZ*(GAMT*TSTA*DCT*(SIET-SIEC))
      DIZB=RDZ*(GAMT*TSBA*DCB*(SIEC-SIEB))
      DIZ=RDZ*(DIZT-DIZB)
C  CALCULATION OF DECAY HEAT  (BTU/LBM*SEC)
      DECHT=4.150934E10*CHI(IK)*SER/(RHOC*WMOLX)
C NOTE. COMPUTATION OF THE NEW SPECIFIC INTERNAL ENTERGY AT N+1 .
      SIE(IK)=SIECO + DT*( -CIR - CIZ + DIR + DIZ +DECHT)
C
C  EQUILIBRIUM MOISTURE THERMODYNAMICS SECTION
      EPS=0.0002
      CIT=CI-SIECO
      TEMPVO=SI(AI,BI,CIT,-1)
      RHOC=AR*TEMPVO*TEMPVO+BR*TEMPVO+CR
      ABTO=(TEMPVO+459.7)*((ZAP(K)/1000.)**.2856)/(1.+0.61*VAP(IK)
     1  /RHOC)/1.8
      EVAP=10.**(-2937.4/ABTO-4.9283*ALOG10(ABTO)+23.5518)
      EVAPD=(2937.4/(ABTO**2)-4.9283/(ALOG(10.)*ABTO))
     1  *ALOG(10.)*EVAP
      RHOSD=RHOC*0.61*EVAPD/ZAP(K)*(TEMPVO+459.7)/(ABTO*1.8)
      RHOSO=RHOC*0.61*EVAP/ZAP(K)*(TEMPVO+459.7)/(ABTO*1.8)
      CIT=CI-SIE(IK)
      TEMPV=SI(AI,BI,CIT,-1)
      RHOC=AR*TEMPV*TEMPV+BR*TEMPV+CR
      ABT=(TEMPV+459.7)*((ZAP(K)/1000.)**.2856)/(1.+0.61*VAP(IK)
     1  /RHOC)/1.8
      EVAP=10.**(-2937.4/ABT-4.9283*ALOG10(ABT)+23.5518)
      RHOS=RHOC*0.61*EVAP/ZAP(K)*(TEMPV+459.7)/(ABT*1.8)
      CSUBP=ACP*TEMPV*TEMPV+BCP*TEMPV+CCP
      IF(LIQ(IK)+VAP(IK)-RHOS) 300,300,320
  300 VAP(IK)=LIQ(IK)+VAP(IK)
      TEMPN=(ABT*1.8-459.7)-LIQ(IK)*1075./(RHOC*CSUBP)
      LIQ(IK)=0.0
      TEMPNV=(TEMPN+459.7)*((1000./ZAP(K))**.2856)*(1.+0.61*VAP(IK)
     1  /RHOC)-459.7
      GO TO 301
  320 IF(VAP(IK)-RHOS) 203,202,203
  203 TEMPCO=ABTO*1.8-459.7
      TEMPC=ABT*1.8-459.7
      TEMPN=((VAP(IK)-RHOS)+(RHOSD*(TEMPCO+459.7)+RHOC*CSUBP*(TEMPC+
     1  459.7)/1075.))/(RHOSD+RHOC*CSUBP/1075.)-459.7
      WATER=CSUBP*RHOC*(TEMPN-TEMPC)/1075.
      VAP(IK)=VAP(IK)-WATER
      LIQ(IK)=LIQ(IK)+WATER
  305 TEMPNV=(TEMPN+459.7)*((1000./ZAP(K))**.2856)*(1.+0.61*VAP(IK)
     1  /RHOC)-459.7
      RHOC=AR*TEMPNV*TEMPNV+BR*TEMPNV+CR
      ABTN=(TEMPN+459.7)/1.8
      EVAP=10.**(-2937.4/ABTN-4.9283*ALOG10(ABTN)+23.5518)
      EVAPD=(2937.4/(ABTN**2)-4.9283/(ALOG(10.)*ABTN))
     1  *ALOG(10.)*EVAP
      RHOS=RHOC*0.61*EVAP/ZAP(K)*(TEMPNV+459.7)/(ABTN*1.8)
      RHOSD=RHOC*0.61*EVAPD/ZAP(K)*(TEMPNV+459.7)/(ABTN*1.8)
      TEMPNN=((VAP(IK)-RHOS)+(RHOSD*(TEMPN+459.7)+RHOC*CSUBP*(TEMPN+
     1  459.7)/1075.))/(RHOSD+RHOC*CSUBP/1075.)-459.7
```

```
      IF(ABS((TEMPN-TEMPNN)/(TEMPNN+459.7)) .LE. EPS) GO TO 308
      DWAT=RHOC*CSUBP*(TEMPNN-TEMPN)/1075.
      LIQ(IK)=LIQ(IK)+DWAT
      VAP(IK)=VAP(IK)-DWAT
      TEMPN=TEMPNN
      GO TO  305
 308  TEMPNV=(TEMPNN+459.7)*((1000./ZAP(K))**.2856)*(1.+0.61*VAP(IK)
     1  /RHOC)-459.7
      RHOC=AR*TEMPNV*TEMPNV+BR*TEMPNV+CR
      ABTN=(TEMPNV+459.7)*((ZAP(K)/1000.)**.2856)/(1.+0.61*VAP(IK)/
     1  RHOC)/1.8
      EVAP=10.**(-2937.4/ABTN-4.9283*ALOG10(ABTN)+23.5518)
      RHOS=RHOC*0.61*EVAP/ZAP(K)*(TEMPNV+459.7)/(1.8*ABTN)
      VAP(IK)=RHOS
      DWAT=RHOC*CSUBP*(TEMPNN-TEMPN)/1075.
      LIQ(IK)=LIQ(IK)+DWAT
      GO TO 301
 202  VAP(IK)=RHOS
      LIQ(IK)=LIQ(IK)
      TEMPNV=TEMPV
 301  CONTINUE
      SIE(IK)=AI*TEMPNV*TEMPNV+BI*TEMPNV+CI
C  CALCULATION OF TERMS IN THE CHI TRANSPORT EQUATION
      CXR=.5*RRC*RDR*( RR*( UC*(CHIC+CHIR) + ALX*ABS(UC)*(CHIC-CHIR) )
     1             - RL*( UL*(CHIL+CHIC) + ALX*ABS(UL)*(CHIL-CHIC) ) )
      CXZ=.5*RDZ*( WC*(CHIC+CHIT) + ALZ*ABS(WC)*(CHIC-CHIT)
     1            - WB*(CHIB+CHIC) - ALZ*ABS(WB)*(CHIB-CHIC) )
       DXRR=RDR*(RR*GAMX*TSRA*DCR*(CHIR-CHIC))
       DXRL=RDR*(RL*GAMX*TSLA*DCL*(CHIC-CHIL))
       DXR=RRC*RDR*(DXRR-DXRL)
       DXZT=RDZ*(GAMX*TSTA*DCT*(CHIT-CHIC))
       DXZB=RDZ*(GAMX*TSBA*DCB*(CHIC-CHIB))
       DXZ=RDZ*(DXZT-DXZB)
      CHI(IK)=CHICO*(1.0-RLAMB*DT)+DT*(-CXR-CXZ+DXR+DXZ)
      GO TO 2650
C NOTE. CALCULATION OF SPECIFIC MATERIAL FOR TEMPERATURE AND
C NOTE. RELATIVE DENSITY .
2591  GO TO ( 2592,2594,2596,2598 ),MAT
C NOTE. CALCULATION OF SODIUM MATERIAL FOR TEMPERATURE AND RHO .
2592  TEMPC=-385.27 + 2.6602*SIEC + 5.9894E-04*SIEC*SIEC +
     1       1.5575E-06*SIEC**3 - 2.9048E-09*SIEC**4 +
     2       1.15427E-12*SIEC**5
      TEMPT=-385.27 + 2.6602*SIET + 5.9894E-04*SIET*SIET +
     1       1.5575E-06*SIET**3 - 2.9048E-09*SIET**4 +
     2       1.15427E-12*SIET**5
      TEMPR=-385.27 + 2.6602*SIER + 5.9894E-04*SIER*SIER +
     1       1.5575E-06*SIER**3 - 2.9048E-09*SIER**4 +
     2       1.15427E-12*SIER**5
      RHOC=59.566 - 7.9504E-3*TEMPC - 0.2872E-6*TEMPC*TEMPC +
     1     0.06035E-9*TEMPC*TEMPC*TEMPC
      RHOT=59.566 - 7.9504E-3*TEMPT - 0.2872E-6*TEMPT*TEMPT +
     1     0.06035E-9*TEMPT*TEMPT*TEMPT
      RHOR=59.566 - 7.9504E-3*TEMPR - 0.2872E-6*TEMPR*TEMPR +
     1     0.06035E-9*TEMPR*TEMPR*TEMPR
      RHOA=0.5*( RHOC+RHOT )
```

```
      RHOAX=0.5*( RHOC+RHOR )
      RHOX=( RHOAX-RHOO )/RHOO
      RHOZ=( RHOA-RHOO )/RHOO
      GO TO 2600
C NOTE. CALCULATION OF WATER  MATERIAL FOR TEMPERATURE AND RHO .
2594  TEMPC=0.9996*SIEC + 32.0002
      TEMPT=0.9996*SIET + 32.0002
      TEMPR=0.9996*SIER + 32.0002
      RHOC=62.742 -0.372E-2*TEMPC - 0.44E-4*TEMPC*TEMPC
      RHOT=62.742 -0.372E-2*TEMPT - 0.44E-4*TEMPT*TEMPT
      RHOA=0.5*( RHOC+RHOT )
      RHOA=0.5*( RHOC+RHOR )
      RHOZ=( RHOA-RHOO )/RHOO
      RHOR=62.742 -0.372E-2*TEMPR - 0.44E-4*TEMPR*TEMPR
      RHOX=( RHOA-RHOO )/RHOO
      GO TO 2600
2596  CIT=CI - SIEC
      TEMPC=SI( AI,BI,CIT,-1 )
      CIT=CI-SIET
      TEMPT=SI( AI,BI,CIT,-1 )
      CIT=CI-SIER
      TEMPR=SI( AI,BI,CIT,-1 )
      RHOC=AR*TEMPC*TEMPC + BR*TEMPC + CR
      RHOT=AR*TEMPT*TEMPT + BR*TEMPT + CR
      RHOR=AR*TEMPR*TEMPR + BR*TEMPR + CR
      RHOA=0.5*( RHOC+RHOT )
      RHOZ=( RHOA-RHOO )/RHOO
      RHOA=0.5*( RHOC+RHOR )
      RHOX=( RHOA-RHOO )/RHOO
      GO TO 2600
2598  CONTINUE
C NOTE. COMPUTATION OF FULL TILDE EQUATIONS AT TIME=N+1 .
2600  IF( ICALI.EQ.2 ) GO TO 2650
      U(IK)=(1./(1.+DT*RXC))*( UCO + DT*( RDX*(PC-PR) + RHOX*GX
     1                        - FUX - FUZ - FCU + FUT ) )
      W(IK)=(1./(1.+DT*RZC))*( WCO + DT*( RDZ*(PC-PT) + RHOZ*GZ
     1                        - FWX - FWZ - FCW + FWT ) )
2650  IF( ICALI.EQ.1 ) GO TO 2700
C NOTE. UPDATING THE Q EQUATION WITH THE RESISTANCE FACTORS .
      RXC=RX(IK)*ABS( UO(IK) )**NRESEX
      RXL=RX(IMK)*ABS( UO(IMK) )**NRESEX
      RZC=RZ(IK)*ABS( WO(IK) )**NRESEX
      RZB=RZ(IKM)*ABS( WO(IKM) )**NRESEX
2700  U(1)=U(IMKS)
      W(1)=W(IMKS)
      TQ(1)=TQ(IMKS)
      TS(1)=TS(IMKS)
      SIE(1)=SIE(IMKS)
      CHI(1)=CHI(IMKS)
      VAP(1)=VAP(IMKS)
      LIQ(1)=LIQ(IMKS)
      SIE(IMKS)=SIEC
      U(IMKS)=UC
      W(IMKS)=WC
      TQ(IMKS)=TQC
```

```
      TS(IMKS)=TSC
      CHI(IMKS)=CHIC
      VAP(IMKS)=VAPC
      LIQ(IMKS)=LIQC
2979  CONTINUE
2989  CONTINUE
      ASSIGN 2990 TO KBC
      IF( NTE.LT.NTPAS ) GO TO 1100
2990  CONTINUE
2999  CONTINUE
      IF( ICALI.EQ.2 ) GO TO 5050
C NOTE. IMPLICIT PRESSURE ITERATION .
4050  IFC=0
      ASSIGN 4100 TO KBC
      GO TO 1100
C NOTE. BEGIN PRESSURE ITERATION AFTER SETING BOUNDARY CONDITIONS .
4100  I1=2
      I2=IBP1
      K1=2
      K2=KBP1
      KK=1
      DO 4489 I=I1,I2
      KK=KK + K2NC
      LWPC=0
      RADD=(FLOAT(I)-1.5)*DX
      RRADD=1./RADD
      IF( CYL.LT.EM6 ) RRADD=0.0
      DO 4479 K=K1,K2
      LWPC=LWPC + NWPC
      IK=KK + LWPC
      IMK=IK - K2NC
      IKM=IK - NWPC
      CFC=CF(IK)
      IF( CFC.NE.1 ) GO TO 4470
      D=RDX*(U(IK)-U(IMK)) + RDZ*(W(IK)-W(IKM)) +.5*RRADD*(U(IK)+U(IMK))
      DTP=-BETA*D
      RXC=RX(IK)*ABS( UO(IK) )**NRESEX
      RXL=RX(IMK)*ABS( UO(IMK) )**NRESEX
      RZC=RZ(IK)*ABS( WO(IK) )**NRESEX
      RZB=RZ(IKM)*ABS( WO(IKM) )**NRESEX
      U(IK)=U(IK) + RDX*DTP/(1.+DT*RXC)
      U(IMK)=U(IMK) - RDX*DTP/(1.+DT*RXL)
      W(IK)=W(IK) + RDZ*DTP/(1.+DT*RZC)
      W(IKM)=W(IKM) - RDZ*DTP/(1.+DT*RZB)
      P(IK)=P(IK) + RDT*DTP
C NOTE. CHECKS FOR CONVERGENCE OF PRESSURE FIELD .
      IF( ABS(D).GT.EPS ) IFC=1
4470  CONTINUE
4479  CONTINUE
4489  CONTINUE
      ITER=ITER + 1
       IF(ITER.LT.1500) GO TO 4510
C NOTE. PRESSURES FAILED TO CONVERGE WITHIN 999 ITERATIONS .
      WRITE(IVDO,50)
       ERF=AMIN1(1.0,.1*NCYC)
```

```
      GO TO 4600
4510  IF( IFC.EQ.1 ) GO TO 4050
4600  ASSIGN 5000 TO KBC
      ITERC=ITER
      ITER=0
      GO TO 1100
C
C NOTE. COMPUTES THE DIVERGENCE ERRORS - ER(IK) .
C
5000  ICALI=2
      GO TO 2030
5050  ASSIGN 5060 TO KBC
      GO TO 1100
5060  ITER=ITERC
      I1=1
      I2=IBP2
      K1=1
      K2=KBP2
      KK=1 - K2NC
      DMX=0.0
      TSMAX=-1.E+20
      TMAX=TSMAX
      WMAX=TMAX
      UMAX=WMAX
      TMIN=+1.E+20
      WMIN=TMIN
      UMIN=WMIN
      PMAX=-1.E+20
      TQMAX=PMAX
      DO 5029 I=I1,I2
      KK=KK + K2NC
      LWPC=-NWPC
      RRADD=1./( (FLOAT(I)-1.5)*DX )
      DO 5019 K=K1,K2
      LWPC=LWPC + NWPC
      IK=KK + LWPC
      IMK=IK - K2NC
      IKM=IK - NWPC
      CFC=CF(IK)
      IF( CFC.NE.1 ) GO TO 5001
      ER(IK)= RDX*( U(IK)-U(IMK)) + RDZ*( W(IK)-W(IKM))
      DMX=AMAX1( DMX,ABS(ER(IK)) )
     1           + .5*CYL*RRADD*( U(IK)+U(IMK))
5001  SIEO(IK)=SIE(IK)
      TQO(IK)=TQ(IK)
      TSO(IK)=TS(IK)
      UO(IK)=U(IK)
      WO(IK)=W(IK)
      SIEO(IK)=SIE(IK)
      CHIO(IK)=CHI(IK)
      VAPO(IK)=VAP(IK)
      LIQO(IK)=LIQ(IK)
      SIEC=SIE(IK)
      IF( CFC.GE.30 ) GO TO 5018
      GO TO( 5002,5004,5006,5008 ),MAT
```

```
C NOTE. COMPUTATION OF TEMPERATURE FOR SODIUM MATERIAL .
5002  TEMP =-385.27 + 2.6602*SIEC + 5.9894E-04*SIEC*SIEC +
     1      1.5575E-06*SIEC**3 - 2.9048E-09*SIEC**4 +
     2      1.15427E-12*SIEC**5
      GO TO 5010
C NOTE. COMPUTATION OF TEMPERATURE FOR WATER MATERIAL .
5004  TEMP=0.9996*SIEC + 32.0002
      GO TO 5010
5006  CIT=CI-SIEC
      TEMP=SI( AI,BI,CIT,-1 )
      GO TO 5010
5008  CONTINUE
5010  UMAX=AMAX1( UMAX,U(IK) )
      WMAX=AMAX1( WMAX ,W(IK) )
      TMAX=AMAX1( TMAX,TEMP )
      TSMAX=AMAX1( TSMAX,TS(IK) )
      UMIN=AMIN1( UMIN,U(IK) )
      WMIN=AMIN1( WMIN,W(IK) )
      TMIN=AMIN1( TMIN,TEMP )
      TQMAX=AMAX1( TQMAX,TQ(IK) )
      PMAX=AMAX1( PMAX,P(IK) )
      IF( I.EQ.IDG .AND. K.EQ.KDG ) GO TO 5012
      GO TO 5018
5012  UDG=U(IK)
      WDG=W(IK)
      TDG=TEMP
      TIM=TIMET + DT
5018  CONTINUE
5019  CONTINUE
5029  CONTINUE
      IF( ERF.LT.1 ) GO TO 10000
      CALL VRPRT
      IF( IPRFM.GT.0 ) CALL VRFLM
      RETURN
C
C NOTE. UPDATES TIME AND NUMBER OF CYCLES .
C
10000 TIMET=TIMET + DT
      NCYC=NCYC + 1
      SMSIE=0.0
      SMCHI=0.0
      FCHI=0.0
      VELCHI=0.0
C     COMPUTE PLUME CENTER AND SIGMA(HEIGHT) FOR CHI DISTRIBUTION
      DO 11150 K=2,KBP1
      DO 11160 I=2,IBP1
      IK=1+NWPC*(((I-1)*KBP2)+K-1)
      CIT=CI-SIE(IK)
      TEMPC=SI(AI,BI,CIT,-1)
      RHOC=AR*TEMPC*TEMPC+BR*TEMPC+CR
      SMSIE=SMSIE+(RHOC*DX*DZ*SIE(IK))
      SMCHI=SMCHI+(CHI(IK)-BKGND)
      FCHI=FCHI+(FLOAT(K)-1.5)*DZ*(CHI(IK)-BKGND)
      VELCHI=VELCHI+WSP(K)*(CHI(IK)-BKGND)
11160 CONTINUE
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11150 CONTINUE
      YPLUME=FCHI/SMCHI
      VELCHI=VELCHI/SMCHI
      DWNDS=DWNDS+VELCHI*DT
      IF( IDIAG.GT.0 ) WRITE(IVDO,51) TIMET,NCYC,ITER,DT,DMX
      IF( IDIAG.EQ.0 ) GO TO 11000
C NOTE. CHECKS ON TIME WHEN TO PRINT  AND/OR PLOT FILM .
      IF (IDATIN.EQ.1) GO TO 11001
11000 IF( TIMET+1.0E-5 .LT. TPRT ) GO TO 11100
      TPRT=TPRT + TPR
      CALL VRPRT
      GO TO 11100
11001 TPRT=TPRT+TPR
11100 IF( IPRFM.LT.1 .OR. TIMET+1.0E-5.LT.TPLT ) GO TO 11200
      TPLT=TPLT + TPL
      WRITE(IVDO,60) YPLUME,VELCHI,DWNDS
   60 FORMAT(' ',15HPLUME CENTER AT,F8.2,6H FEET.,15H PLUME SPEED IS,
     1F8.2,22H  DOWNWIND DISTANCE IS,F6.0)
      WRITE(IVDO,63) SMSIE
  63  FORMAT(4H    ,'TOTAL  ENERGY   ON MESH IS  ',E12.5)
      WRITE(IVDO,51) TIMET,NCYC,ITER,DT,DMX
      CALL VRFLM
11200 CONTINUE
C  TIMING SECTION FOR RESTARTING PROGRAM ON A COARSER MESH
11300 IF(TIMET+1.0E-5.LT.TRSTRT(NRSTRT)) GO TO 11400
      CALL COARSE
      NRSTRT=NRSTRT+1
      DR=DX
      RDR=RDX
      RDRS=1./(DR*DR)
      RDRM=RDR
      RDRP=RDRM
      RDZM=RDZ
      RDZP=RDZM
      WRITE(IVDO,40) TIMET,DX,DZ
  40  FORMAT(22H  PROGRAM RESTART AT   ,F10.3,12H SECONDS    ,'  DX = ',
     AF6.2,'  DZ = ',F6.2)
      CALL VRPRT
11400 CONTINUE
C NOTE. CHECKS ON TIME WHEN TO WRITE MAG TAPE FILE .
12000 IF( TWTD.GE.1.E+5 ) GO TO 12100
      IF (IDATIN.EQ.1) GO TO 12001
      IF( TIMET+1.0E-5 .LT. TWTD ) GO TO 12100
      TWTD=TWTD + TTD
      CALL TAPWRI
      GO TO 12100
12001 TWTD=TWTD+TTD
C NOTE. COMPUTATION OF SPECIFIC DIAGNOSTIC VARIABLES .
12100 GO TO KDIAG,( 12200,12500,13000 )
C NOTE. OUTPUT OF DIAGNOSTIC VARIABLES IF IDIAG=1 FROM CARD NO. 3 .
12200 WRITE(IVDO,54) IDG,KDG,UDG,WDG,TDG,UMAX,UMIN,WMAX,WMIN,TMAX,TMIN
     1 ,TSMAX,EPS
C
C NOTE. COMPUTATION OF TIMING IN VARIOUS PORTIONS OF THE PROGRAM .
C
```

```
12500  IF( TIMET+1.E-10 .LT. TFIN ) GO TO 13000
C
C NOTE. CHECKS ON TIME WHEN TO FINISH .
C
13000 IF( TSTEP.LT.EM6 ) GO TO 13010
      IF( NCYC.LT.2 ) GO TO 13010
      ALENG=AMIN1( DX,DZ )
      VEL=AMAX1( UMAX,WMAX )
      IF( VEL.GT.EM6 ) DT=TSTEP*ALENG/VEL
      DTDIF=TSTEP*RDXDZS/TSMAX
      VELNEW=AMAX1( UMAX,WMAX )
      TAUDT=0.20*VELNEW/( VELNEW-VELOLD+EM6 )
      TAUDT=ABS( TAUDT )
      DT=AMIN1( DT,DTDIF,TAUDT )
      RDT=1./DT
13010 IDATIN=0
      IF( TIMET+1.0E-5 .LT. TFIN ) GO TO 100
      RETURN
C ***** FORMATS ***** FORMATS ***** FORMATS ***** .
   50 FORMAT(1H ,75H *** ERROR 004 - PRESSURES FAILED TO CONVERGE WITHIN
     1 1500  ITERATIONS . ***)
   51 FORMAT(1H ,5HTIME=,1PE12.4,3H , ,14HCYCLE NUMBER =,I5,3H , ,
     1 28H PRESSURE ITERATION NUMBER =,I4,3H , ,4HDT =,E12.4,3H , ,
     2 16HMAX DIVERGENCE =,E12.4)
   52 FORMAT(1H ,5X,62H THE FOLLOWING DIAGNOSTICS OCCUR AFTER TIME HAS B
     1EEN UPDATED .)
   54 FORMAT(1H ,5X,2HI=,I3,3H K=,I3,4H  U=,1PE12.5,4H  W=,E12.5,
     1 4H  T=,E12.5,3H * ,6H UMAX=,E12.5,6H UMIN=,E12.5/6H WMAX=,E12.5,
     2 6H WMIN=,E12.5,17X,7H  TMAX=,E12.5,7H  TMIN=,E12.5,7H TSMAX=,
     3 E12.5/7H   EPS=,E12.5)
   55 FORMAT(1H ,5X,10HTIME/CYC =,1PE10.3,10H TOT TIME=,E10.3,
     1 10HI/O T/CYC=,E10.3,10H TOT I/O =,E10.3)
      END
```

The Planetary Boundary Layer Code Listing

```
C       ************PLANETARY BOUNDARY LAYER MODEL************
       IMPLICIT REAL*8(A-H,O-Z)
        COMMON/DATA/ Z(80),U(80),T(80),Y(80),DZ(80),DUDZ(80),DTDZ(80),
     1   YLAMD(80),UU(80),VV(80),WW(80),UW(80),UT(80),WT(80),TT(80),
     2  DUU(80),DVV(80),DWW(80),DUW(80),DUT(80),DWT(80),DTT(80),
     3  BUU(80),BVV(80),BWW(80),BUW(80),BUT(80),BWT(80),BTT(80),
     4  QUU(80),QVV(80),QWW(80),QUW(80),QUT(80),QWT(80),QTT(80),
     5  PUU(80),PVV(80),PWW(80),PUW(80),PUT(80),PWT(80),PTT(80),
     6  TKE(80),TEMPZ(80),CLAM1(80),CLAM2(80),CLAM3(80),SLAM(80),
     7 RHOZ(80),DRODZ(80),REYND(80),X(25),EUU(80),EVV(80),EWW(80),
     8 D(10),C(4),ICHNG(8),DET(4),SUM(11),EUW(80),EUT(80),EWT(80)
     9 ,ETT(80),TKEN(80),RLUU(80),RLVV(80),RLWW(80),RLUW(80),RLUT(80),
     A  RLTT(80),RATIO(80),RLWT(80),UUO(80),VVO(80),WWO(80),UWO(80)
     B  ,UTO(80),WTO(80),TTO(80),TIME(80),TETAZ(80)
C         ALL VARIABLES ARE SET EQUAL TO ZERO
      DO 3 J=1,6138
      Z(J)=0.0D0
    3 CONTINUE
C          ********  INPUT OUTPUT STATEMENTS  ********
C        READS THE MODEL UNIVERSAL CONSTANTS , THE CONTROL PARAMETERS
C (MESH SIZE, TIME STEP ) ,THE TEMPERATURE AND WIND PROFILES. THIS IS
C   DONE IN THE M.K.S.A UNIT SYSTEM
      READ (5,100) IFREQ,JL,JLFM,IDIAG,DTAU,TMAX,CTE
      READ (5,101) K,IDEG,C1,C2,C3,A,B,ALP,GAM,SQREN
      READ (5,102) RHOO,TEMPO,VISC,CSUBP,ZO,YKO,VGEOS,FOMEG,HF,DE99
      DO 1 I=1,K
      READ (5,103) X(I),U(I),T(I)
    1 CONTINUE
C       WRITE ALL THE INPUT VARIABLES AND THE PROFILES
      WRITE (6,200) IFREQ,JL,JLFM,DTAU,TMAX,CTE
      WRITE (6,300) IDIAG
  300 FORMAT (' IDIAG = ',I3)
      WRITE (6,201) K,IDEG,C1,C2,C3,A,B,ALP,GAM,SQREN
      WRITE (6,202) RHOO,TEMPO,VISC,CSUBP,ZO,YKO,VGEOS,FOMEG,HF,DE99
      WRITE (6,203)
      DO 2 I=1,K
      WRITE (6,208) X(I),U(I),T(I)
    2 CONTINUE
C
  100 FORMAT (4(5X,I3),2(5X,D12.5),D13.6)
  603 FORMAT (7D15.5)
  101 FORMAT (2(5X,I2),/,5(D9.2,5X),/,D9.2,5X,D9.2,D12.5)
  102 FORMAT (2D11.4,D10.3,D11.4,D9.2,/,D9.2,D10.3,D10.3,D10.3,D11.4,
     1 D10.3)
  103 FORMAT (3(10X,D10.3))
  200 FORMAT(' ATMOSPHERIC TURBULENCE MODEL WITH PARAMETERS ',//,
     1  '  IFREQ    =',I4,/,'  JL       =',I3,/,'  JLFM      =',I3,
     2  /,'  DTAU    =',F8.3,/,'  TMAX    =',F8.3,/,'  CTE      =',D13.6)
  201 FORMAT ('  K        =',I3,/,'  IDEG     =',I3,/,
     1  '  C1       =',D10.3,/,'  C2       =',D10.3,/,'  C3       =',
     2  D10.3,/,'  A        =',D10.3,/,'  B       =',D10.3,/,
     3  '  ALP      =',D10.3,/,'  GAM      =',D10.3,/,'  SQREN  =',D12.5)
  202 FORMAT ('  RHOO     =',D11.4,/,'  TEMPO   =',D11.4,/,'  VISC    =',
     1     D13.6,/,'  CSUBP   =',D14.2,/,'  ZO      =',D9.2,/,'  YKO
     2     =',D11.2,/,'  VGEOS    =',D11.3,/,'  FOMEG  =',D11.4,/,'  HF
```

```
    3      =',D12.2,/,'  DE99     =',D12.3,//)
 203  FORMAT ('THE HEIGHT DEPENDENT PROFILES ARE ')
 208  FORMAT (3(10X,D10.3))
 204  FORMAT ('  AT A TIME TAU   =',F8.3,/)
 205  FORMAT ('  THE HEIGHT DEPENDENT CORRELATION FUCTIONS ARE :',//,
    1  '          Z(J)            UU(J)           VV(J)           WW(J)',
    2 '         UW(J)           UT(J)           WT(J)           TT(J)',
    3 '         TKE(J)',//)
 206  FORMAT (9D14.5)
C
      GRAV=9.8D0
      NX=M
      M2=0
      JLP1=JL+1
      JLFMP=JLFM+1
      JLM1=JL-1
      ICOUNT =0
C   INITIALISATION .ALSO CALCULATE THE TURBULENCE MODEL FREE CONSTANTS
C DO THIS IN THE LOGARITHMIC MESH INTERVAL OF DOMAIN
      DO 48 J=2,JLFM
      Z(J)=(-1.0D0)*HF*ALOG(1.-(J-1.)/FLOAT(JLFM))/SQREN
      XEND=Z(J)
      TETAZ(J)=TEMPO*(1.-GRAV/(CSUBP*TEMPO)*Z(J))
      TEMPZ(J)=TETAZ(J)+0.0098*Z(J)
      RHOZ(J)=RHOO*((1.-GRAV/(CSUBP*TEMPO)*Z(J))**(1./(GAM-1.)))
      DRODZ(J)=-RHOO*(1./(GAM-1.))*(GRAV/(CSUBP*TEMPO))*
     1 ((1.-(GRAV*Z(J))/(CSUBP*TEMPO))**(1./(GAM-1.)-1.))
      YLAMD(J)=ALP*DSQRT(A)*(Z(J)+ZO)/(1.+ALP*DSQRT(A)*(Z(J)+ZO)/
     1 (C1*DE99))
      CLAM1(J)=YLAMD(J)
      CLAM2(J)=C2*YLAMD(J)
      CLAM3(J)=C3*YLAMD(J)
      IDIAG1=1
      IF (IDIAG1 .EQ. 1) GO TO 33
      GO TO 90
  33  IF (Z(J) .GT. 15.) GO TO 31
      DTDZ(J)=-0.32301284124D0/Z(J)
      GO TO 32
  31  DTDZ(J)=0.0D0
  32  CONTINUE
      DUDZ(J)=1.33542974113D0/Z(J)
  90  CONTINUE
      DZ(J)=Z(J)-Z(J-1)
      RATIO(J)=DTAU/DZ(J)**2
      UU(J)=0.02D0
      VV(J)=0.02D0
      WW(J)=0.02D0
      TT(J)=0.0D0
      TKE(J)=DSQRT(UU(J)+VV(J)+WW(J))
      REYND(J)=RHOZ(J)*TKE(J)*CLAM1(J)/VISC
      SLAM(J)=CLAM1(J)/DSQRT(A+B*REYND(J))
 501  FORMAT(D12.5)
  48  CONTINUE
C DO THIS IN THE LINEAR MESH OF DOMAIN
      DO 5 J=JLFMP,JLP1
```

```
      Z(J)=(-1.0D0)*HF*ALOG(1./FLOAT(JLFM))/SQREN+(J-JLFMP+1)*HF*
     1 0.69D0/SQREN
      XEND=Z(J)
      TETAZ(J)=TEMP0*(1.-GRAV/(CSUBP*TEMPO)*Z(J))
      TEMPZ(J)=TETAZ(J)+0.0098*Z(J)
      RHOZ(J)=RHO0*((1.-GRAV/(CSUBP*TEMPO)*Z(J))**(1./(GAM-1.)))
      DRODZ(J)=-RHO0*(1./(GAM-1.))*(GRAV/(CSUBP*TEMPO))*
     1 ((1.-(GRAV*Z(J))/(CSUBP*TEMPO))**(1./(GAM-1.)-1.))
      YLAMD(J)=ALP*DSQRT(A)*(Z(J)+Z0)/(1+ALP*DSQRT(A)*(Z(J)+Z0)/
     1 (C1*DE99))
      CLAM1(J)=YLAMD(J)
      CLAM2(J)=C2*YLAMD(J)
      CLAM3(J)=C3*YLAMD(J)
      IF (IDIAG1 .EQ. 1) GO TO 34
      GO TO 91
   34 IF (Z(J) .GT. 15.) GO TO 36
      DTDZ(J)=-0.23334D0/Z(J)
      GO TO 35
   36 DTDZ(J)=0.0D0
   35 CONTINUE
      DUDZ(J)=1.87302D0/Z(J)
   91 CONTINUE
      UU(J)=0.02D0
      VV(J)=0.02D0
      WW(J)=0.02D0
      TT(J)=0.0D0
      DZ(J)=DZ(JLFM)
      RATIO(J)=DTAU/DZ(J)**2
      TKE(J)=DSQRT(UU(J)+VV(J)+WW(J))
      REYND(J)=RHOZ(J)*TKE(J)*CLAM1(J)/VISC
      SLAM(J)=CLAM1(J)/DSQRT(A+B*REYND(J))
    5 CONTINUE
      DO 98 J=1,14
      DUDZ(J)=DUDZ(7)
   98 CONTINUE
C  PERFORM LEAST SQUARE FIT OF POINTWISE WIND PROFILE TO A POLYNOMIAL
C  IN THE FORM U(Z)/U(Z0)=A0+.....+AN*X**N, N=4
      IF(IDIAG1 .EQ. 1) GO TO 83
      N=4
      IB=4
      M=1
      DO 45 J=1,11
      SUM(J)=0.0D0
   45 CONTINUE
      DO 41 J=1,K
      SUM(1)=SUM(1)+X(J)**2
      SUM(2)=SUM(2)+X(J)**3
      SUM(3)=SUM(3)+X(J)**4
      SUM(4)=SUM(4)+X(J)**5
      SUM(5)=SUM(5)+X(J)**6
      SUM(6)=SUM(6)+X(J)**7
      SUM(7)=SUM(7)+X(J)**8
      SUM(8)=SUM(8)+U(J)*X(J)
      SUM(9)=SUM(9)+U(J)*X(J)**2
      SUM(10)=SUM(10)+U(J)*X(J)**3
```

```
      SUM(11)=SUM(11)+U(J)*X(J)**4
   41 CONTINUE
      D(1)=SUM(1)
      D(2)=SUM(2)
      D(3)=SUM(3)
      D(4)=SUM(3)
      D(5)=SUM(4)
      D(6)=SUM(5)
      D(7)=SUM(4)
      D(8)=SUM(5)
      D(9)=SUM(6)
      D(10)=SUM(7)
      C(1)=SUM(8)
      C(2)=SUM(9)
      C(3)=SUM(10)
      C(4)=SUM(11)
      IJOB=0
C  SUBROUTINE LEQ1S PERFORMS THE LEAST SQUARE FITTING
      CALL LEQ1S (D,N,C,M,IB,IJOB,ICHNG,DET,IER)
      WRITE(6,47) C(1),C(2),C(3),C(4)
C  PERFORM LEAST SQUARE FIT OF POINTWISE TEMPERATURE PROFILE TO A
C  POLYNOMIAL IN,N=3THE FORM T(Z)/T(Z0)=C0+.....C0*X**N
      DO 28 J=1,JL
      DUDZ(J)=C(1)+2*C(2)*Z(J)+3*C(3)*Z(J)**2+4*C(4)*Z(J)**3
   28 CONTINUE
      DO 9 J=1,11
      SUM(J)=0.0D0
    9 CONTINUE
      DO 42 J=1,K
      SUM(1)=SUM(1)+1.0D0
      SUM(2)=SUM(2)+X(J)**1
      SUM(3)=SUM(3)+X(J)**2
      SUM(4)=SUM(4)+X(J)**3
      SUM(5)=SUM(5)+X(J)**4
      SUM(6)=SUM(6)+X(J)**5
      SUM(7)=SUM(7)+X(J)**6
      SUM(8)=SUM(8)+T(J)
      SUM(9)=SUM(9)+T(J)*X(J)**1
      SUM(10)=SUM(10)+T(J)*X(J)**2
      SUM(11)=SUM(11)+T(J)*X(J)**3
   42 CONTINUE
      D(1)=SUM(1)
      D(2)=SUM(2)
      D(3)=SUM(3)
      D(4)=SUM(3)
      D(5)=SUM(4)
      D(6)=SUM(5)
      D(7)=SUM(4)
      D(8)=SUM(5)
      D(9)=SUM(6)
      D(10)=SUM(7)
      C(1)=SUM(8)
      C(2)=SUM(9)
      C(3)=SUM(10)
      C(4)=SUM(11)
```

```
      IJOB=0
      CALL LEQ1S (D,N,C,M,IB,IJOB,ICHNG,DET,IER)
      DO 29 J=1,JL
      DTDZ(J)=C(2)+2*C(3)*Z(J)+3*C(4)*Z(J)**2
   29 CONTINUE
      WRITE(6,47) C(1),C(2),C(3),C(4)
   47 FORMAT( 4D20.6)
   83 CONTINUE
      DO 97 J=2,JL
      WRITE(6,208) Z(J),DUDZ(J),DTDZ(J)
   97 CONTINUE
      TAU=0.0
    6 TAU=TAU+DTAU
      ICOUNT=ICOUNT+1
C
C
      DO 7 J=2,JL
      DUU(J)=(UU(J)-UU(J-1))/DZ(J)
      DVV(J)=(VV(J)-VV(J-1))/DZ(J)
      DWW(J)=(WW(J)-WW(J-1))/DZ(J)
      DUW(J)=(UW(J)-UW(J-1))/DZ(J)
      DUT(J)=(UT(J)-UT(J-1))/DZ(J)
      DWT(J)=(WT(J)-WT(J-1))/DZ(J)
      DTT(J)=(TT(J)-TT(J-1))/DZ(J)
    7 CONTINUE
C
      DO 8 J=2,JL
      QUU(J)=-(TKE(J)/CLAM1(J))*(UU(J)-(TKE(J)**2)/3.)-RLUU(J)*DUU(J)/
     1 RATIO(J)
      QVV(J)=-(TKE(J)/CLAM1(J))*(VV(J)-(TKE(J)**2)/3.)-RLVV(J)*DVV(J)
     1 /RATIO(J)
      QWW(J)=-(TKE(J)/CLAM1(J))*(WW(J)-(TKE(J)**2)/3.)-RLWW(J)*DWW(J)
     1 /RATIO(J)
      QUW(J)=-TKE(J)*UW(J)/CLAM1(J)-(DRODZ(J)/RHOZ(J))*CLAM3(J)*DUW(J)*
     1 TKE(J)-RLUW(J)*DUW(J)/RATIO(J)
      QUT(J)=-TKE(J)*UT(J)/CLAM1(J)-RLUT(J)*DUT(J)/RATIO(J)
      QWT(J)=-TKE(J)*WT(J)/CLAM1(J)+(DRODZ(J)/RHOZ(J))*CLAM3(J)*TKE(J)*
     1 DWT(J)-RLWT(J)*DWT(J)/RATIO(J)
      QTT(J)=-RLTT(J)*DTT(J)/RATIO(J)
      PUU(J)=-2.*UW(J)*DUDZ(J)-2.*VISC*UU(J)/(SLAM(J)**2)
      PVV(J)=-2*VISC*VV(J)/(SLAM(J)**2)
      PWW(J)=2*GRAV*WT(J)/TEMPZ(J)-2*VISC*WW(J)/(SLAM(J)**2)
      PUW(J)=-2*VISC*UW(J)/(SLAM(J)**2)+GRAV*UT(J)/TEMPZ(J)-WW(J)*
     1 DUDZ(J)
      PUT(J)=-2*VISC*UT(J)/(SLAM(J)**2)-UW(J)*DTDZ(J)-WT(J)*DUDZ(J)
      PWT(J)=-2*VISC*WT(J)/(SLAM(J)**2)+GRAV*TT(J)/TEMPZ(J)-WW(J)*
     1 DTDZ(J)
      PTT(J)=-2*VISC*TT(J)/(SLAM(J)**2)-2*WT(J)*DTDZ(J)
    8 CONTINUE
C
C
C
C    **********CALCULATE THE NEW CORRELATIONS**********
      DO 12 J=2,JL
      UU(J)=UU(J)+DTAU*(QUU(J)+PUU(J))
```

```
      VV(J)=VV(J)+DTAU*(QVV(J)+QWW(J))
      WW(J)=WW(J)+DTAU*(QWW(J)+PWW(J))
      UW(J)=UW(J)+DTAU*(QUW(J)+PUW(J))
      UT(J)=UT(J)+DTAU*(QUT(J)+PUT(J))
      WT(J)=WT(J)+DTAU*(QWT(J)+PWT(J))
      TT(J)=TT(J)+DTAU*(QTT(J)+PTT(J))
      TKE(J)=DSQRT(UU(J)+VV(J)+WW(J))
   12 CONTINUE
      DO 80  J=2,JL
      RLUU(J)=-(CLAM2(J)*TKE(J)+VISC)*RATIO(J)
      RLVV(J)=RLUU(J)
      RLWW(J)=-(3.*CLAM2(J)*TKE(J)+2.*CLAM3(J)*TKE(J)+VISC)*RATIO(J)
      RLUW(J)=-(2.*CLAM2(J)*TKE(J)+CLAM3(J)*TKE(J)+VISC)*RATIO(J)
      RLUT(J)=RLUU(J)
      RLWT(J)=-(2.*CLAM2(J)*TKE(J)+CLAM3(J)*TKE(J)+VISC)*RATIO(J)
      RLTT(J)=-(2.*CLAM2(J)*TKE(J)+VISC)*RATIO(J)
   80 CONTINUE
C
      DO 81  J=2,JLM1
      BUU(J)=1.0-2.0*RLUU(J)
      BVV(J)=1.0-2.0*RLVV(J)
      BWW(J)=1.0-2.0*RLWW(J)
      BUW(J)=1.0-2.0*RLUW(J)
      BUT(J)=1.0-2.0*RLUT(J)
      BWT(J)=1.0-2.0*RLWT(J)
      BTT(J)=1.0-2.0*RLTT(J)
   81 CONTINUE
C
      BUU(JL)=1.0-RLUU(JL)
      BVV(JL)=1.0-RLVV(JL)
      BWW(JL)=1.0-RLWW(JL)
      BUW(JL)=1.0-RLUW(JL)
      BUT(JL)=1.0-RLUT(JL)
      BWT(JL)=1.0-RLWT(JL)
      BTT(JL)=1.0-RLTT(JL)
C
      DO 82  J=1,JL
      EUU(J)=UU(J)
      EVV(J)=VV(J)
      EWW(J)=WW(J)
      EUW(J)=UW(J)
      EUT(J)=UT(J)
      EWT(J)=WT(J)
      ETT(J)=TT(J)
   82 CONTINUE
C
C     SOLVE FOR INTERMEDIATE CORRELATION FUNCTIONS
C
      CALL TRIDAG(2,JL,RLUU,BUU,RLUU,EUU,UU)
      CALL TRIDAG(2,JL,RLVV,BVV,RLVV,EVV,VV)
      CALL TRIDAG(2,JL,RLWW,BWW,RLWW,EWW,WW)
      CALL TRIDAG(2,JL,RLUW,BUW,RLUW,EUW,UW)
      CALL TRIDAG(2,JL,RLUT,BUT,RLUT,EUT,UT)
      CALL TRIDAG(2,JL,RLWT,BWT,RLWT,EWT,WT)
      CALL TRIDAG(2,JL,RLTT,BTT,RLTT,ETT,TT)
```

```
C
C
C
      DO 85 J=2,JL
      TKE(J)=DSQRT(UU(J)+VV(J)+WW(J))
   85 CONTINUE
      IMIN=7
C
C
C   TEST FOR CONVERGENCE
C
      IF(DABS((UU(IMIN)-UUO(IMIN))/UU(IMIN)) .LE. 0.0005) GO TO 70
C
C   SAVE THE OLD TIME STEP VALUES FOR THE CONVERGENCE TEST
C
C
C
      DO 72 J=2,JL
      UUO(J)=UU(J)
      VVO(J)=VV(J)
      WWO(J)=WW(J)
      UWO(J)=UW(J)
      UTO(J)=UT(J)
      WTO(J)=WT(J)
      TTO(J)=TT(J)
   72 CONTINUE
C          ***********PRINT THE CORRELATIONS WHEN APPROPRIATE**********
      IF (ICOUNT.NE.IFREQ) GO TO 13
      ICOUNT=0
      WRITE(6,204) TAU
      WRITE (6,205)
      DO 14 J=1,JL
      WRITE (6,206) Z(J),UU(J),VV(J),WW(J),UW(J),UT(J),WT(J),
     1 TT(J),TKE(J)
   14 CONTINUE
      IF (TAU .GE. 999.0) GO TO 50
      IF (IDIAG.EQ. 1) GO TO 24
   50 IFREQ=1
      DO 26 K=1,JL
      WRITE(6,603) Z(K),DUDZ(K),DTDZ(K)
   26 CONTINUE
      DO 27 K=1,JL
      WRITE(6,206) Z(K),DUU(K),DVV(K),DWW(K),DUW(K),DUT(K),DWT(K),DTT(K)
   27 CONTINUE
      DO 21 K=1,JL
      WRITE(6,603) BUU(K),BVV(K),BWW(K),BUW(K),BUT(K),BWT(K),BTT(K)
   21 CONTINUE
      DO 22 K=1,JL
      WRITE(6,603) QUU(K),QVV(K),QWW(K),QUW(K),QUT(K),QWT(K),QTT(K)
   22 CONTINUE
      DO 23 K=1,JL
      WRITE(6,603) PUU(K),PVV(K),PWW(K),PUW(K),PUT(K),PWT(K),PTT(K)
   23 CONTINUE
   24 CONTINUE
   13 IF((TAU-TMAX).LE.0.0D0) GO TO 6
```

```
   70 WRITE(6,204)   TAU
      WRITE (6,205)
      DO 73 J=1,JL
      WRITE(6,206) Z(J),UU(J),VV(J),WW(J),UW(J),UT(J),WT(J),
     1  TT(J),TKE(J)
   73 CONTINUE
      END
       IMPLICIT REAL*8(A-H,O-Z)
      SUBROUTINE TRIDAG(IF,L,A,B,C,D,V)
      DIMENSION A(1),B(1),C(1),D(1),V(1),BETA(101),GAMMA(101)
C
C  COMPUTE INTERMEDIATE ARRAYS BETA AND GAMMA
      BETA(IF)=B(IF)
      GAMMA(IF)=D(IF)/BETA(IF)
      IFP1=IF+1
      DO 1 I=IFP1,L
      BETA(I)=B(I)-A(I)*C(I-1)/BETA(I-1)
      GAMMA(I)=(D(I)-A(I)*GAMMA(I-1))/BETA(I)
    1 CONTINUE
C
C  COMPUTE FINAL SOLUTION VECTOR
      V(L)=GAMMA(L)
      LAST=L-IF
      DO 2 K=1,LAST
      I=L-K
      V(I)=GAMMA(I)-C(I)*V(I+1)/BETA(I)
    2 CONTINUE
      RETURN
      END
```

The Entrainment Model Code Listing

```
C     PROGRAM ZNFINL
      DATA R/287./,G/9.8/,TWO/2./,PI/3.1416/,P622/.622/,
     1 RV/461./,T273/273./,ES0/610.8/,ZERO/0./,CPD/1003./,
     2 ADIA/.009763/,ONE/1./,SIXI/.61/,CL/4186./,CV/1810./,
     3 ESHP62/.0038/,HRV273/19.8528/,TWOPI/6.2832/,EL/2500000 /,
     4 E/1.0/,DUW/0.0/
      REAL*8 HSPEED,HHUM,HTEMP
      DATA  HSPEED/'VELOCT'/,HHUM/'RELHUM'/,HTEMP/'TEMP'/
      DIMENSION COORDX(60),COORDY(60)
      COMMON /RLVAR/ A,AF1,AF2,B,DT,DTO,H,P,Q,QA,RD1,RD2
     2,SIG,SIGA,T,TA,U,UW,V,X,Z,WIDTH,HEIGHT,DELTAX,DELTAZ,YMINO,YMAXO
     3,XMINS,XMAXS,YMINS,YMAXS,TICSIX,STEPSZ,XADV,YADV,XSCALE,ZSCALE
      COMMON /INTVAR/ IESWCH,IPSWCH,IRSWCH,ITERA,IWSWCH,MARK
     2,MM,MULTOW,NPRINT,ICODE,NSIG,ITERB
      COMMON /AMB/ ZRHAMB(25), RHAMB(25),ZWSAMB(25),WSAMB(25)
     2,ZTAMB(25),TAMB(25)
      COMMON /NUMAMB/ NRELHM,NWNDSP,NTEMP
      ISTOP=0
      CALL READIN(ISTOP)
      IF (MULTOW .EQ. 1) CALL READIN(ISTOP)
210   FORMAT (4F7.2)
      MTSAVE=MULTOW
      DO 999 K= 1,ITERA
      CALL READIN(ISTOP)
12    FORMAT(1X,2F5.1,2F7.4,2F6.3)
      CALL READIN(STOP)
      XSCALE=1.2*XMAXS
      ZSCALE=1.2*YMAXS
      IF(IESWCH .EQ. 0) GO TO 2
      EX= EXP(HRV273*(T-T273)/T)
2     IF(IPSWCH.EQ.0)Q=ES0*P622*EX/(P-ES0*EX)
2042  FORMAT(10A8)
2041  FORMAT(26I3)
       CALL READIN(ISTOP)
         CALL READIN(ISTOP)
2044  FORMAT(4(2X,F6.1,F6.3,1X,F6.1))
204   FORMAT(8(F5.1,F5.0))
2049  FORMAT(16F5.1)
      CALL ZZGRAT(Z,UW,WSAMB,ZWSAMB,NWNDSP,HSPEED)
         WRITE(6,3050) UW
      CALL ZZGRAT(Z,TA,TAMB,ZTAMB,NTEMP,HTEMP)
         WRITE (6 3050) TA
      CALL ZZGRAT(Z,RHA,RHAMB,ZRHAMB,NRELHM,HHUM)
         WRITE (6,3050) RHA
3050     FORMAT (' INTERPOLATED VALUE=',F8.2)
      EX= EXP(HRV273*(TA-T273)/TA)
      QAS=ES0*P622*EX/(P-ES0*EX)
      PEX=P-ES0*EX
      QA= RHA*QAS
      AK= SQRT(V*V+U*U)/UW
      DENA=P/R/TA/(ONE+SIXI*QA)*(ONE+SIGA)
      DEN= P/R/T /(ONE+SIXI*Q )*(ONE+SIG )
      FR= V/SQRT((DENA-DEN)/DEN*TWO*B*G)
      VEL=SQRT(U*U+ V*V)
      TSTIME=XMAXS/UW/500.
```

```
      DD=B*TWO
      BO=DD
      PMEVAP=  PI*B*B*H*DEN
      PM=PMEVAP
      BC= B
      V1=VEL
      U0=U
      PMO=PM
      PO=P
       TO=T
      QO=Q+SIG
      ELMOD=CL*T273+EL-CV*T273
C  PLOT THE OUTLINES OF THE PLUME.
      DZ=ZERO
      S=ZERO
      DB=ZERO
      WRITE(6,2041)K,K,K,K,K,K,K,K,K,K,K,K,K,K,K,K,K,K,K
      WRITE(6,9)
9     FORMAT('     K    FR     RH                   A      E')
      WRITE(6,12)AK,FR,DTO,DUW,A,E,RHA
      WRITE (6,8)
8     FORMAT('------MODEL INPUT (LINE 1) AND MODEL OUTPUT------',/,
     1'       X        Z RADIUS  INNER  ELEMENT    MASS  PROJECT  ASPIR
     2 PLUME   AMB HORIZ   VER TOTAL  WIND    PLUME      AMB      COND'
     3,/,19X,'    RADIUS    WIDTH              ENTRAIN  ENTRAIN  TEMP  TEMP
     4VEL   VEL    VEL    VEL MOISTURE MOISTURE MOISTURE  RH',/,5X,
     5'(M)      (M)     (M)     (M)',6X,'(M)       (KG)      (KG)      (KG)    (K
     6)  (K) (M/S) (M/S) (M/S) (M/S)  (KG/KG)  (KG/KG)  (KG/KG) (*)')
      ITRACR=0
      CSAT=1.
      C=1.
      ISTLOP=1
      MULTOW=MTSAVE
      ENASP=ONE
      ENCYL=ONE
      DO 99 J= 1,ITERB
C  THE LINES UW= UW+ DUW*DZ AND TA= ETC. HAVE BEEN REMOVED IN THIS
C  VERSION.
      P= P-DENA*G*DZ
      DMDTH=B/TWO*(U/VEL-U0/V1)
      IF (DMDTH .LT. ZERO) DMDTH= ZERO
      IF(MULTOW.EQ.1) GO TO 15
      GO TO 208
  15  ENASP=ASFACT(B,RD1,RD2,AF1,AF2)
      ENCYL=ENASP
 208  EINS=E*DENA*UW*DT*B*H*(ENCYL*TWO*V/VEL+PI/DD*(U*DB/VEL+DMDTH))
      ZWEI= A*DENA*TWOPI*B*H*DT*ABS(UW*U/VEL-VEL)*ENASP
      DM= EINS
      IF (ZWEI .GT. EINS) DM= ZWEI
      GAMMA= DM/.00695555/PM
      DTI= DT
      DT= DT/GAMMA
      IF (DT .LT. TSTIME)GO TO 108
      RSCALE=TSTIME/DTI
      EINS=RSCALE*EINS
```

```
      ZWEI=RSCALE*ZWEI
      DM= DM*RSCALE
      DT= TSTIME
      GO TO 109
108   EINS= EINS/GAMMA
      DM= DM/GAMMA
      ZWEI= ZWEI/GAMMA
109   IF(J.EQ.1)WRITE(6,13)X,Z,B,BC,H,PM,EINS,ZWEI,T,TA,U,V,VEL,UW,Q,
     1QA,SIG
      SUM= PM+DM
      U0= U
      U= (PM*U+DM*UW)/SUM
      T=(PM*T+DM*TA)/SUM
      Q= (Q*PM+QA*DM)/SUM
      QOLD=Q
      EX= EXP(HRV273*(T-T273)/T)
      QST=ES0*P622*EX/(P-ES0*EX)
      IF(SIG .LE. ZERO .AND. Q .LE. QST) GO TO 110
      IF (SIG .GT. ZERO) GO TO 111
      WRITE(6,13)X,Z,B,BC,H,PM,EINS,ZWEI,T,TA,U,V,VEL,UW,Q
111   SIG=(SIG*PM+SIGA*DM)/SUM
      ARG= HRV273*T273/T/T
      ENT=CPD*T+Q*CV*(T-T273)+Q*CL*T273+EL*Q+CL*T*SIG
      DELT=(ENT-(CPD+CL*(SIG+Q)-CL*QST+CV*QST)*T-QST*ELMOD)/
     1(CPD+CL*(SIG+Q)+(ELMOD*ARG+CV+CV*ARG*T-CL-T*CL*ARG)*QST)
      T= T+DELT
      EX= EXP(HRV273*(T-T273)/T)
      Q=ES0*P622*EX/(P-ES0*EX)
      SIG= QOLD-Q+SIG
      IF(SIG.LT.ZERO) SIG=ZERO
      IF(SIG .NE. ZERO)GO TO 110
      PMEVAP=PM
      CSAT=PM0/PMEVAP
      ITRACR= 0
      WRITE(6,13)X,Z,B,BC,H,PM,EINS,ZWEI,T,TA,U,V,VEL,UW,Q,QA
110   DENA=P/R/TA/(ONE+SIXI*QA)*(ONE+SIGA)
      DEN= P/R/T /(ONE+SIXI*Q )*(ONE+SIG )
      V= (PM*V       )/SUM          +(DENA-DEN)*G/DEN*DT
      PM= SUM
      V1= VEL
      VEL= SQRT(U*U+ V*V)
      DZ= V*DT
      DX= U*DT
      DD= VEL*DT
      H= H+ (VEL-V1)/DD*H*DT
      BSAVE= B
      B= SQRT(PM/(DEN*PI*H))
      DB= B-BSAVE
      X= X+ DX
      Z= Z+DZ
      T= T- T/TA*ADIA*DZ
      S= S+ DD
      CALL ZZGRAT(Z,TA,TAMB,ZTAMB,NTEMP,HTEMP)
      CALL ZZGRAT(Z,RHA,RHAMB,ZPHAMB,NRELHM,HHUM)
      XBUOY=G*(B**2)*V*((T-TA)/TA)/(UW**3)
```

```
      EX=EXP(HRV273*(TA-T273)/TA)
      QAS=ES0*P622*EX/(P-ES0*EX)
      QA=RHA*QAS
      IF (SIG.GT.ZERO) GO TO 214
      IF (BC.GT.(B*.5)) GO TO 115
      CPEAK=3.37*PM0/PM
      C=CSAT
      CALL QZ(Q,Q0,T,T0,C,PM,PM0,CSAT,P,P0)
      ISTATE=0
      IF (CSAT.LE.CPEAK) ISTATE=1
      IF (ISTLOP.EQ.0) GO TO 114
      ISTLOP=0
      ISAVE=ISTATE
114   IF (ISTATE.EQ.ISAVE) GO TO 214
      ISAVE=ISTATE
      GO TO 214
115   IF(ITRACR .EQ. 1) GO TO 214
      WRITE(6,13)X,Z,B,BC,H,PM,EINS,ZWEI,T,TA,U,V,VEL,UW
      ITRACR=1
214   IF (J/NPRINT-(J-1)/NPRINT .NE. 1) GO TO 99
      IF((X-BC) .GT. XBUOY) GO TO 999
      IF (Z .GT. ZSCALE .OR. X .GT. XSCALE) GO TO 999
      IF (SIG.GT.ZERO) GO TO 215
      CPEAK=3.37*PM0/PM
      C=CSAT
      CALL QZ(Q,Q0,T,T0,C,PM,PM0,CSAT,P,P0)
      IF (CSAT.GT.CPEAK) GO TO 215
C  +++ZZGRADIENT INTERPOLATES AMBIENT VALUES OF TA,UW AND QA.
215   CALL ZZGRAT(Z,UW,WSAMB,ZWSAMB,NWNDSP,HSPEED)
      IF (IESWCH .EQ. ZERO) GO TO 97
      IF(CSAT.GT.CPEAK.OR.SIG.GT.ZERO) GO TO 971
      BC=B/TWO-B/PI*ASIN(TWO*CSAT /(CPEAK)-1)
      XU= X-BC*V/VEL
      ZU= Z+BC*U/VEL
      XL= X+BC*V/VEL
      ZL= Z-BC*U/VEL
971   XU= X-B*V/VEL
      ZU= Z+B*U/VEL
      XL= X+B*V/VEL
      ZL= Z-B*U/VEL
97    WRITE(6,13)X,Z,B,BC,H,PM,EINS,ZWEI,T,TA,U,V,VEL,UW,Q,QA,SIG,RHA
13    FORMAT(1X,4F7.2,4E9.2,2F6.1,4F6.2,3E9.2,F4.2)
99    CONTINUE
999   CONTINUE
      AI=0.0000043
      BI=0.171
      CI=78.357
      ICELTP=1
      T=(T-273)*9./5.+32.0
      SIEI=AI*T*T+BI*T+CI
      CHII=0.0
      VAPI=0.0795*Q
      LIQI=0.0795*SIG
      UI=0.0
      WI=V
```

```
      ZNM=(ZU-ZL)/DELTAZ
      AK1=AINT(ZNM)
      AK2=AINT(ZNM)+ONE
      DELTAK=(AK2-AK1)/(ZNM-AK1)
      IF(DELTAK .GE. ONE) AK=AK2
      AK=AK1
      XNM=(ZU-ZL)/DELTAX
      AJ1=AINT(XNM)
      AJ2=AINT(XNM)+ONE
      DELTAJ=(AJ2-AJ1)/(XNM-AJ1)
      IF(DELTAJ .GE. ONE) AJ=AJ2
      AJ=AJ1
      IF((ZL/DELTAZ-AINT(ZL/DELTAZ)) .GE. 0.5) NB1=INT(ZL/DELTAZ)+1
      NB1=INT(ZL/DELTAZ)
      NB=NB1
      NT=NB+INT(AK)
      NL=2
      NR=2
    7 WRITE(6,3) NL,NR,NB,NT,ICELTP
      WRITE(6,4) SIEI,TQI,TSI,UI,WI,CHII,VAPI,LIQI
    3  FORMAT(4I5,I2)
    4  FORMAT(6F8.3,2F8.6)
      IF(NT .EQ. NB .OR. NR .EQ. (AJ+ONE)) GO TO  1
      IF(NT-NB .EQ. ONE) GO TO 1
      NT=NT-1
      NB=NB+1
      NR=NR+1
      NL=NL+1
      GO TO 7
    1  CONTINUE
      CALL EXIT
      END
      SUBROUTINE ZZGRAT(Z,ARGUE,ZDAMB,ZAMB,NUMARR,HTYPE)
      DIMENSION ZDAMB(25),ZAMB(25)
      DATA ISAVE/0/
      IFLAG=0
      J=2
      IF (Z.LT.ZAMB(1)) GO TO 103
      DO 101  J=2,NUMARR
      IF (Z  .LT.ZAMB(J)) GO TO 102
101   CONTINUE
103   IFLAG=1
      IF (ISAVE.NE.IFLAG) WRITE (6,1001) HTYPE,Z
1001  FORMAT (' A VALUE IS EXTRAPOLATED FOR ',A8,
     1' AT A HEIGHT OF ',F8.2)
102   GRAD = (ZDAMB(J)-ZDAMB(J-1))/(ZAMB(J)-ZAMB(J-1))
      ARGUE= ZDAMB(J-1)+ GRAD*(Z- ZAMB(J-1))
      ISAVE=IFLAG
      RETURN
      END
      FUNCTION ASFACT(B,RD1,RD2,AF1,AF2)
      REAL M
      IF (B.GT.RD1) GO TO 10
      ASFACT=AF1
      RETURN
```

```
10    IF (B.GE.RD2) GO TO 20
      M=(AF2-AF1)/(RD2-RD1)
      ASFACT=AF2+(B-RD2)*M
      RETURN
20    MULTOW=0
      ASFACT=1
      RETURN
      END
      SUBROUTINE QZ(Q,Q0,T,T0,C,PM,PM0,CSAT,P,P0)
      QABAR=(PM*Q-PM0*Q0)/(PM-PM0)
      TABAR=(PM*T-PM0*T0*(P/P0)**.286)/(PM-PM0)
      JCOUNT=1
100   JCOUNT=JCOUNT+1
      IF (JCOUNT.GT.25) GO TO 777
      CALL QSUB(QDIF,QABAR,Q0,TABAR,T0,C,QC,QSC)
      IF (QDIF .LT. .00001) GO TO 887
      C=C+.0001
      CALL QSUB(Q2,QABAR,Q0,TABAR,T0,C,QC,QSC)
      IF (Q2 .LT. .00001) GO TO 887
      DQDC=(Q2-QDIF)/.0001
      DELC=-QDIF/DQDC
      C=C+DELC
      GO TO 100
777   WRITE (61,102)
102   FORMAT (' NO CONVERGENCE')
888   WRITE (61,103) C,QDIF,QSC,QC
103   FORMAT (' C=',F10.9,' QDIF=',F10.9,' QSC=',F10.9,' QC=',F10.9)
      RETURN
887   CSAT=C
      RETURN
      END
      SUBROUTINE QSUB (QDIF,QABAR,Q0,TABAR,T0,C,QC,QSC)
      QC=(1.-C)*QABAR+C*Q0
      TC=(1.-C)*TABAR+C*T0
      EX=EXP(19.8523*(TC-273.)/TC)
      QSC=610.8*.622*EX/(100000-610.8*EX)
      QDIF=QSC-QC
      RETURN
      END
      SUBROUTINE READIN(ISTOP)
C
C THE FOLLOWING SUBROUTINE IS USED FOR INPUTING THOSE VARIABLES
C NEEDED IN THE MAIN PROGRAM
C
      COMMON /RLVAR/ REALV(37)
      COMMON /INTVAR/ INTV(12)
      COMMON /AMB/ AMBVAL(150)
      COMMON /NUMAMB/ NAMB(3)
      REAL*8 VNREAL(37)
      REAL*8 VNINT(12)
      DATA VNREAL/5HA    ,5HAF1  ,5HAF2  ,5HB    ,5HDT   ,
     15HDT0  ,5HH    ,5HP    ,5HQ    ,5HQA   ,5HRD1  ,5HRD2  ,
     25HSIG  ,5HSIGA ,5HT    ,5HTA   ,5HU    ,5HUW   ,5HV    ,
     35HX    ,5HZ    ,5HWIDTH,6HHEIGHT,6HDELTAX,6HDELTAZ,5HYMIN0,
     45HYMAX0,5HXMINS,5HXMAXS,5HYMINS,5HYMAXS,6HTICSIZ,6HSTEPSZ,
```

```
     55HXADV ,5HYADV ,6HXSCALE,6HZSCALE/,VNINT/6HIESWCH,6HIPSWCH
     6,6HIRSWCH,5HITERA,6HIWSWCH,5HMARK ,5HMM    ,6HMULTOW,6HNPRINT,
     75HICODE,5HNSIG ,5HITERB/
      REAL*8 DUMMY(9),VARTYP,AMBCON,VN,TSTEND
      DATA DUMMY/'AMB     ','END     ','VAR     ','ENDV    ',
     1'RELH    ','WDSP    ','TEMP    ','ENDA    ','ENDC    '/
C
C THE FOLLOWING STATEMENTS DETERMINE WHICH OF THE TWO SUBSTATES ARE
C TO BE ENTERED OR WHETHER TO RETURN TO THE MAIN PROGRAM
C
10    READ (5,20) VARTYP
20    FORMAT (A8,F10.3)
      IF (VARTYP .EQ. DUMMY(1)) GO TO 110
      IF (VARTYP .EQ. DUMMY(2))  GO TO 200
      IF (VARTYP .EQ. DUMMY(3)) GO TO 30
C
C IF THE INPUT IS NEITHER 'AMB','END',OR 'VAR' THEN THE INPUT IS GARBAGE
C
      WRITE (6,25) VARTYP
25    FORMAT (' NO VARIABLE TYPE NAMED :',A8)
      GO TO 10
C HERE WE DETERMINE WHETHER THE VARIABLE IS REAL OR INTEGER AND WHICH
C OF THE REAL OR INTEGER VARIABLES IT IS. TEN WE JUMP TO THE APPROPRIATE
C LOCATION
C
30    READ (5,20) VN,VV
      IF (VN.EQ. DUMMY(4)) GO TO 10
      DO 40 I=1,37
         IF (VN .EQ. VNREAL(I)) GO TO 55
40    CONTINUE
      DO 80 I=1,12
         IF (VN .EQ. VNINT(I)) GO TO 105
80    CONTINUE
      WRITE (6,90) VN
C
C IF NO GO TO HAS BEEN MADE INEITHER OF THE DO LOOPS THEN THERE
C IS NO VARIABLE BY THE NAME INPUT
C
90    FORMAT (' NO VARIABLE NAMED :',A8)
      ISTOP=1
      GO TO 30
C
C BELOW THE VALUE IS ASSIGNED TO THE VARIABLE
C
55    REALV(I)=VV
      WRITE (6,57) VN,VV
57    FORMAT (' ',A8,'=',F10.2)
      GO TO 30
105   INTV(I)=VV
      WRITE (6,107) VN,INTV(I)
107   FORMAT (' ',A8,'=',I10)
      GO TO 30
C
C THE FOLLOWING INPUTS THE AMBIENT CONDITIONS
C FIRST IT IS DETERMINED WHICH OF THE AMBIENT CONDITIONS IS TO BE INPUT
```

```
C
110   READ (5,20) AMBCON
      I=-1
      IF (AMBCON .EQ. DUMMY(5)) I=0
      IF (AMBCON .EQ. DUMMY(6)) I=50
      IF (AMBCON .EQ. DUMMY(7)) I=100
      IF (AMBCON .EQ. DUMMY(8)) GO TO 10
C
C IF I=-1 HERE THEN THE INPUT IS GARBAGE
C
      IF (I.EQ.-1) GO TO 142
C
C THE VARIABLE K IS USED TO INPUT THE NUMBER OF CONDITIONS THAT ARE
C INPUT INTO THE PROPER LOCATION IN THE ARRAY NAMB
C
      K=I/50+1
C
C I, J ARE USED TO INPUT THE VALUES INTO THE CORRECT LOCATIONS IN THE
C AMBVAL ARRAY.
C ILIM IS USED TO INSUR THAT NO MORE THAN 25 AMBIENT CONDITIONS ARE INPU
C
      ILIM=I+25
      NAMB(K)=0
120   READ (5,125) TSTEND,HEIGHT,COND
125   FORMAT (A8,F10.3,F10.3)
      I=I+1
      IF (TSTEND .EQ. DUMMY(9)) GO TO 110
      AMBVAL(I)=HEIGHT
      J=I+25
      AMBVAL(J)=COND
      NAMB(K)=NAMB(K)+1
      WRITE(6,130) AMBCON,HEIGHT,COND
 130  FORMAT(' THE ',A8,'AT AHEIGHT ',F10.2,' IS ',F10.3)
      IF (I .LT. ILIM) GO TO 120
      WRITE(6,135) AMBCON
 135  FORMAT(' TOO MANY INPUT AMB. COND. FOR ',A6)
      ISTOP=1
C
C AT THIS POINT WE KEEP READING IN THE AMBIENT VALUES, ESSENTIALLY
C IGNORING THEM UNTIL WE COME TO THE END OF THE SET
C
140   READ(5,125) TSTEND
      IF(TSTEND .EQ. DUMMY(9)) GO TO 110
      GO TO 140
142   WRITE(6,145) AMBCON
145   FORMAT(' NO AMBIENT CONDITION NAMED :',A8)
      ISTOP=1
      GO TO 140
200   RETURN
      END
```

APPENDIX E

USER'S MANUAL

E.1 THE TURBULENCE MODEL INPUT DECK

A listing of the input variables is given in E.1.1. Figure E.1.1 represents the input deck of the turbulence model for the Paradise case (P2-3). The plume code requires the knowledge of the turbulent input profiles, it is therefore necessary to run the turbulence model prior to use of the plume model. The turbulence model yields all the atmospheric turbulent fluctuations including the turbulence kinetic energy on the turbulence kinematic viscosity. Table E.1.2 shows a typical output of the model. In order to obtain stable results it is important to tune the time step properly. The magnitude of the time step is chosen arbitrarily and depends strongly on the amplitude of the wind shear. Therefore for each case a proper tuning is needed to obtain a stable solution. Time steps of the order of 0.5 sec are typical and convergence is usually reached after 50 sec.

```
      20       90      40       1       0.5D0            150.0D0       -0.002D0
      23        8
    .15D0        0.1D0          0.1D0            2.5D0         .125D0
  .44D0            1.4D0    1838.0D0
     1.3D0     239.0D0    .000018D0 1005.0D0     0.0D0
    0.4D0     7.0D0     .0001D0 60000.D0  1000.0D0
               0.0D0               2.50D0                0.592D0
               50.0D0              2.63D0                 0.65[illegible]D0
               100.0D0             2.75D0                 0.725D0
               150.0D0             2.88D0                 0.791D0
               200.0D0             3.00D0                 0.858D0
               250.0D0             3.13D0                 0.925D0
               300.0D0             3.25D0                 0.993D0
               350.0D0             3.38D0                 1.060D0
               400.0D0             3.50D0                 1.128D0
               450.0D0             3.63D0                 1.196D0
               500.0D0             3.75D0                 1.265D0
               550.0D0             3.88D0                 1.333D0
               600.0D0             4.00D0                 1.402D0
               650.0D0             4.13D0                 1.471D0
               700.0D0             4.25D0                 1.541D0
               750.0D0             4.38D0                 1.610D0
               800.0D0             4.50D0                 1.680D0
               850.0D0             4.63D0                 1.750D0
               900.0D0             4.75D0                 1.820D0
               950.0D0             4.88D0                 1.891D0
               1000.0D0            5.00D0                 1.962D0
               1100.0D0            5.25D0                 2.105D0
               1200.0D0            5.50D0                 2.248D0
               1300.0D0            6.00D0                 2.393D0
               1400.0D0            6.25D0                 2.539D0
               1500.0D0            6.50D0                 2.686D0
               1600.0D0            6.75D0                 2.834D0
               1700.0D0            7.00D0                 2.983D0
               1800.0D0            7.25D0                 3.133D0
               1900.0D0            7.50D0                 3.285D0
```

Figure E.1.1

Sample Deck for the Turbulence Model
Paradise (P2-3) Case

E.1.1 INPUT DATA DESCRIPTION FOR ATMOSPHERIC TURBULENCE MODEL

The following list presents the input data requirements for the atmospheric turbulence model. For each data card the individual data are defined, and the card format is given.

CARD NO. 1 IFREQ, JL, JLFM, IDIAG, DTAU, TMAX, CTE

FORMAT (4(5X, I3, 2(5X, D12.5), (D13.6))

IFREQ = frequency at which the output is printed (cycles)

JL = total number of mesh points (including fine mesh)

JLFM = total number of points in the fine mesh

IDIAG = diagnostic parameters, = 1, prints diagnostic material

$\neq$ 1, no printout of diagnostics

DTAU = time increment, depends on the windshear, and temperature gradient

TMAX = maximum time allowed for convergence ($\sim$100 sec)

CTE = dummy constant, unimportant

CARD NO. 2 K, IDEG FORMAT (2(5X, I2))

K = number of data points in the input profile

IDEG = dummy constant, unimportant

CARD NO. 3 C_1, C_2, C_3, A, B FORMAT (5(D9.2, 5X))

C_1 = model universal constant	C_1 = 1.5
C_2 = " " "	C_2 = 1.0
C_3 = " " "	C_3 = 1.0
A = " " "	A = 2.5
B = " " "	B = 0.125

CARD NO. 4 ALP, GAM, SQREN FORMAT ( ))

ALP = model universal constant ALP = 0.44

GAM = C_p/C_v

SQREN = Re , square root of the Reynolds number

$$Re = \frac{\rho \Lambda_1 q}{\mu} \qquad Re = 1838$$

<u>CARD NO. 5</u> RHOO, TEMPO, VISC, CSUBP, Z_0

FORMAT (2011.4, D10.3, D11.4, D9.2)

RHOO = reference density, must be compatible with the reference density of the plume model

TEMPO = reference temperature (potential temperature), must also be compatible with the reference temperature of the plume model

VISC = molecular viscosity of air VIS = $1.8\ 10^{-5} m^2/s$

CSUBP = heat capacity of air CSUBP = 1005 J/Kg.^{0}K

Z_0 = roughness parameter $Z_0 = 0$

<u>CARD NO. 6</u> YKO, VGEOS, F_0MEG, HF, DE99

FORMAT (D9.2, D10.3, D10.3, D10.3, D11.4, D10.3)

YKO = Von Karman constant YKO = 0.4

VGEOS = magnitude of the geostrophic wind (M/S)

F_0MEG = frequency parameter of the coriolis force

HF = height which corresponds to the top of the fine mesh

DE99 = height of the P.B.L. in meters (m) obtained from the height at which the wind speed reaches 99% of its maximum amplitude.

<u>CARD NO. 7</u> X(I), U(I), T(I) FORMAT (3(10x, D10.3))

X(I) = height of the Ith mesh point

U(I) = velocity at the Ith mesh point

T(I) = temperature at the Ith mesh point

This card is repeated K times.

THE HEIGHT DEPENDENT CORRELATION FUCTIONS ARE :

Z(J)	UU(J)	VV(J)	WW(J)	UW(J)	UT(J)	WT(J)	TT(J)	TKE(J)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.82648D+00	0.63885D-03	0.10885D-02	0.57006D-03	-0.14094D-03	0.51782D-05	-0.10830D-04	0.12154D-05	0.47932D-01
0.16744D+01	0.94999D-03	0.11816D-02	0.70949D-03	-0.31497D-03	0.18551D-04	-0.24254D-04	0.29337D-05	0.53301D-01
0.25450D+01	0.12023D-02	0.12206D-02	0.77601D-03	-0.45398D-03	0.31904D-04	-0.35154D-04	0.41557D-05	0.56559D-01
0.34394D+01	0.13856D-02	0.12119D-02	0.80688D-03	-0.55572D-03	0.42744D-04	-0.43254D-04	0.49726D-05	0.58347D-01
0.43590D+01	0.15198D-02	0.11944D-02	0.82278D-03	-0.62985D-03	0.51106D-04	-0.49246D-04	0.55277D-05	0.59472D-01
0.53053D+01	0.16194D-02	0.11763D-02	0.83178D-03	-0.68464D-03	0.57500D-04	-0.53750D-04	0.59134D-05	0.60228D-01
0.62798D+01	0.16941D-02	0.11596D-02	0.83729D-03	-0.72574D-03	0.62397D-04	-0.57196D-04	0.61855D-05	0.60753D-01
0.72843D+01	0.17505D-02	0.11448D-02	0.84093D-03	-0.75693D-03	0.66153D-04	-0.59873D-04	0.63781D-05	0.61125D-01
0.83207D+01	0.17932D-02	0.11317D-02	0.84351D-03	-0.78072D-03	0.69027D-04	-0.61977D-04	0.65130D-05	0.61388D-01
0.93911D+01	0.18253D-02	0.11203D-02	0.84548D-03	-0.79886D-03	0.71209D-04	-0.63642D-04	0.66047D-05	0.61571D-01
0.10498D+02	0.18489D-02	0.11102D-02	0.84709D-03	-0.81256D-03	0.72837D-04	-0.64966D-04	0.66630D-05	0.61694D-01
0.11643D+02	0.18659D-02	0.11013D-02	0.84848D-03	-0.82271D-03	0.74013D-04	-0.66015D-04	0.66949D-05	0.61770D-01
0.12831D+02	0.18772D-02	0.10933D-02	0.84975D-03	-0.82995D-03	0.74815D-04	-0.66841D-04	0.67053D-05	0.61808D-01
0.14063D+02	0.18839D-02	0.10862D-02	0.85094D-03	-0.83476D-03	0.75302D-04	-0.67483D-04	0.66980D-05	0.61815D-01
0.15343D+02	0.18867D-02	0.10799D-02	0.85211D-03	-0.83751D-03	0.75519D-04	-0.67969D-04	0.66756D-05	0.61796D-01
0.16675D+02	0.18861D-02	0.10742D-02	0.85328D-03	-0.83847D-03	0.75503D-04	-0.68322D-04	0.66402D-05	0.61754D-01
0.18065D+02	0.18826D-02	0.10690D-02	0.85445D-03	-0.83785D-03	0.75280D-04	-0.68559D-04	0.65934D-05	0.61693D-01
0.19516D+02	0.18764D-02	0.10643D-02	0.85566D-03	-0.83583D-03	0.74872D-04	-0.68693D-04	0.65364D-05	0.61614D-01
0.21035D+02	0.18678D-02	0.10601D-02	0.85690D-03	-0.83252D-03	0.74297D-04	-0.68736D-04	0.64701D-05	0.61520D-01
0.22627D+02	0.18570D-02	0.10561D-02	0.85818D-03	-0.82801D-03	0.73567D-04	-0.68694D-04	0.63952D-05	0.61411D-01
0.24302D+02	0.18441D-02	0.10525D-02	0.85951D-03	-0.82237D-03	0.72693D-04	-0.68574D-04	0.63120D-05	0.61288D-01
0.26067D+02	0.18294D-02	0.10492D-02	0.86090D-03	-0.81564D-03	0.71680D-04	-0.68382D-04	0.62211D-05	0.61152D-01
0.27933D+02	0.18128D-02	0.10462D-02	0.86236D-03	-0.80784D-03	0.70535D-04	-0.68119D-04	0.61224D-05	0.61003D-01
0.29912D+02	0.17945D-02	0.10433D-02	0.86388D-03	-0.79898D-03	0.69260D-04	-0.67787D-04	0.60161D-05	0.60841D-01
0.32018D+02	0.17743D-02	0.10407D-02	0.86547D-03	-0.78904D-03	0.67855D-04	-0.67388D-04	0.59021D-05	0.60667D-01
0.34271D+02	0.17524D-02	0.10382D-02	0.86715D-03	-0.77797D-03	0.66318D-04	-0.66921D-04	0.57801D-05	0.60480D-01
0.36690D+02	0.17287D-02	0.10359D-02	0.86893D-03	-0.76572D-03	0.64646D-04	-0.66383D-04	0.56499D-05	0.60278D-01
0.39303D+02	0.17030D-02	0.10337D-02	0.87080D-03	-0.75220D-03	0.62832D-04	-0.65771D-04	0.55108D-05	0.60063D-01
0.42143D+02	0.16754D-02	0.10317D-02	0.87280D-03	-0.73729D-03	0.60867D-04	-0.65079D-04	0.53621D-05	0.59832D-01
0.45254D+02	0.16456D-02	0.10297D-02	0.87493D-03	-0.72082D-03	0.58738D-04	-0.64302D-04	0.52029D-05	0.59584D-01
0.48694D+02	0.16135D-02	0.10278D-02	0.87721D-03	-0.70257D-03	0.56426D-04	-0.63427D-04	0.50320D-05	0.59317D-01
0.52539D+02	0.15787D-02	0.10260D-02	0.87968D-03	-0.68223D-03	0.53907D-04	-0.62441D-04	0.48476D-05	0.59029D-01
0.56898D+02	0.15409D-02	0.10243D-02	0.88238D-03	-0.65938D-03	0.51149D-04	-0.61325D-04	0.46472D-05	0.58716D-01
0.61930D+02	0.14995D-02	0.10226D-02	0.88534D-03	-0.63339D-03	0.48102D-04	-0.60049D-04	0.44278D-05	0.58373D-01
0.67882D+02	0.14536D-02	0.10209D-02	0.88868D-03	-0.60333D-03	0.44696D-04	-0.58571D-04	0.41845D-05	0.57993D-01
0.75166D+02	0.14021D-02	0.10191D-02	0.89247D-03	-0.56769D-03	0.40822D-04	-0.56823D-04	0.39100D-05	0.57564D-01
0.84557D+02	0.13427D-02	0.10173D-02	0.89691D-03	-0.52380D-03	0.36292D-04	-0.54693D-04	0.35920D-05	0.57069D-01
0.97793D+02	0.12718D-02	0.10149D-02	0.90216D-03	-0.46658D-03	0.30753D-04	-0.51975D-04	0.32087D-05	0.56470D-01
0.12042D+03	0.11828D-02	0.10111D-02	0.90809D-03	-0.38730D-03	0.23525D-04	-0.48379D-04	0.27286D-05	0.55696D-01
0.14294D+03	0.11215D-02	0.10076D-02	0.91177D-03	-0.31767D-03	0.18294D-04	-0.45861D-04	0.24199D-05	0.55145D-01
0.16547D+03	0.10812D-02	0.10048D-02	0.91326D-03	-0.26579D-03	0.14652D-04	-0.44548D-04	0.22461D-05	0.54766D-01
0.18799D+03	0.10551D-02	0.10002D-02	0.91118D-03	-0.22552D-03	0.12182D-04	-0.44389D-04	0.21957D-05	0.54465D-01
0.21052D+03	0.10390D-02	0.99756D-03	0.90828D-03	-0.19793D-03	0.10636D-04	-0.45393D-04	0.22598D-05	0.54266D-01
0.23304D+03	0.10295D-02	0.99293D-03	0.90175D-03	-0.18095D-03	0.98354D-05	-0.47515D-04	0.24422D-05	0.54076D-01
0.25557D+03	0.10249D-02	0.98962D-03	0.89413D-03	-0.17361D-03	0.96894D-05	-0.50737D-04	0.27545D-05	0.53932D-01
0.27809D+03	0.10237D-02	0.98534D-03	0.88378D-03	-0.17453D-03	0.10169D-04	-0.55004D-04	0.32168D-05	0.53785D-01
0.30062D+03	0.10254D-02	0.98152D-03	0.87185D-03	-0.18249D-03	0.11298D-04	-0.60274D-04	0.38571D-05	0.53654D-01
0.32314D+03	0.10298D-02	0.97742D-03	0.85784D-03	-0.19617D-03	0.13134D-04	-0.66486D-04	0.47108D-05	0.53526D-01
0.34567D+03	0.10368D-02	0.97344D-03	0.84211D-03	-0.21433D-03	0.15760D-04	-0.73579D-04	0.58203D-05	0.53408D-01
0.36819D+03	0.10467D-02	0.96943D-03	0.82463D-03	-0.23573D-03	0.19269D-04	-0.81481D-04	0.72340D-05	0.53298D-01
0.39071D+03	0.10593D-02	0.96546D-03	0.80554D-03	-0.25915D-03	0.23750D-04	-0.90112D-04	0.90063D-05	0.53201D-01
0.41324D+03	0.10748D-02	0.96154D-03	0.78489D-03	-0.28343D-03	0.29277D-04	-0.99406D-04	0.11197D-04	0.53115D-01
0.43576D+03	0.10929D-02	0.95769D-03	0.76280D-03	-0.30745D-03	0.35900D-04	-0.10926D-03	0.13868D-04	0.53041D-01
0.45829D+03	0.11132D-02	0.95391D-03	0.73936D-03	-0.33016D-03	0.43628D-04	-0.11958D-03	0.17089D-04	0.52976D-01
0.48081D+03	0.11350D-02	0.95023D-03	0.71467D-03	-0.35057D-03	0.52426D-04	-0.13027D-03	0.20928D-04	0.52914D-01
0.50334D+03	0.11575D-02	0.94665D-03	0.68885D-03	-0.36777D-03	0.62202D-04	-0.14122D-03	0.25457D-04	0.52849D-01
0.52586D+03	0.11796D-02	0.94320D-03	0.66200D-03	-0.38096D-03	0.72800D-04	-0.15233D-03	0.30749D-04	0.52771D-01
0.54839D+03	0.11999D-02	0.93988D-03	0.63426D-03	-0.38942D-03	0.83994D-04	-0.16349D-03	0.36877D-04	0.52669D-01

Sample Output Deck for Turbulence Model
Paradise (P2-3) Case

E.2. INPUT CARD SYNOPSIS FOR BUOYANT PLUME MODELING

Introduction:

The input required for the buoyant plume model is similar to that described in M.I.T. EL-79-004 except for the variable "Model". This variable allows the user to select one of the two turbulence models available.

In this work only the k-σ model has been used (Model=0) although the k-ε model is available (Model=1). This is due to the fact that the k-ε model has not been validated in plume use.

E.2.1 INPUT DATA DESCRIPTION FOR THE PLUME MODEL

The following list presents the input data requirements for the Turbulent Buoyant Plume Model. For each data card the individual data are defined and the card format is given.

Card No. 1: IBR, KBR, IPRFM, MODEL (Format 2 (5X, 15), 7X, I2, 36X, I2), where:

IBR • the number of real zones in the x direction, (= -1 to terminate the problem). Current print routine requires IBR = 20.

KBR • the number of real zones in the z direction. Current print routine requires KBR = 20.

IPRFM • 1 for line printer output and plume statistical information.

Model • variable used to select turbulence model

Model=0 k-σ model
Model=1 k-ε model

Card No. 2: LABEL (Format 10A8), where:

- Columns 2-80 of this card are used for problem identification on print output.
- Column 1 should not be used since it is treated as a carriage control.
- If desired, the card may be blank, but it must be included.

Card No. 3: DT, TPRT, TPLT, TWTD, TFIN, ITAPW, NPRT, IDIAG, LPR, IOBS, IDG, KDG (Format 5F8.3, 5I2, 2I3), where:

DT • δt, the initial time increment.
Usually set equal to 10^{-2} sec.

TPRT • Elapsed time between printings of output. Usually 10 to 100 sec.

TPLT • Elapsed time between output of plume statistical information. Usually 1 to 10 sec.

TWTD • Must be larger than TFIN below.

TFIN • Time when to finish problem.

Note: The above parameters, DT, TPRT, TPLT, TWTD and TFIN, must be in problem units, i.e., these parameters have dimension of time in seconds.

ITAPW • Tape write file number. Unimportant in this version of VARR II.

NPRT • Initial print cycles where: 0 = no print during cycles 0-1 unless overridden by TPRT, 1 = print during cycle. 0 only, 2 = prints occurring during cycles 0 and 1. Usually NPRT = 2.

IDIAG • Per cycle diagnostic information, where:

- 0 = no diagnostic information will be output on the printer,
- 1 = specific diagnostic information. The following quantities allow the user to monitor the problem between print intervals: i and k indices for a specific cell, velocities and temperature for a specific cell, followed by u, w and temperature maximum and minimum values. Also, maximum σ is printed out.

LPR • Line printer control; LPR = 3 should be used.

IOBS • IOBS must = 1.

IDG • the i indice of the specific diagnostic cell.

KDG • the k indice of the specific diagnostic cell.

Note: IDG, KDG identify a specific cell in the mesh whose temperature and velocities will be printed each cycle if IDIAG = 1. IDG and KDG are necessary only if IDIAG = 1.

Card No. 4: DX, DZ, GX, GZ, ALX, ALZ, CYL, B_o, EPS, VMIN (Format 10F8.3) where:

DX • δx, the constant cell size in the x direction for the mesh region.

DZ • δz, the constant cell size in the z direction for the mesh region.

Note: DX and DZ must be in problem units, i.e., these constant cell sizes have dimension of distance in feet.

GX • g_x, gravity felt by the fluid in the x direction.

• In our case GX = 0.

GZ • g_z, gravity felt by the fluid in the z direction.

• In our case, GZ = -32.2 ft/sec^2,

ALX • α_x, the donor cell coefficient for the convection terms in the i direction.

ALZ • α_z, the donor cell coefficient for the convection terms in the k direction.

<u>Note</u>: We take both values equal to 1 (full donor cell) because we feel that they best represent the real physical situation.

CYL • 1.0 for cylindrical geometry or
• 0.0 for plane geometry.

<u>Note</u>: We always use <u>planar</u> geometry in the context of the plume model

B_0 • β_o, the pressure iteration relaxation parameter. β_o is a relaxation factor used in calculating the pressure iteration $\delta p\ \delta t$ term. In general, $1.4 \leq \beta_o \leq 1.7$ seems to be adequate for most problems but the user is urged to try β_o values larger than 1.7. However, $\beta_o > 2$ may be unstable and leads to non-convergence of the pressure iteration. In our calculations the conservative value of $\beta_o = 1.6$ is used.

EPS • The pressure iteration percent of error in divergence criterion, typically set equal to -10^{-3}. (The minus sign simply tells the program to keep EPS constant.)

VMIN • The minimum velocity for the variable ε calculation. VMIN is unimportant, and is usually set to 10.0 for simplicity.

Card No. 5: KWR, KWL, KWT, KWB, FSLIP, ALP, GAM ALP_0, GANU, TQJET, TSJET (Format 4I2, 8F8.3), where:

KWR • Right boundary wall parameter, KWR = 1 in our case.

KWL • Left boundary wall parameter, KWL = 1 " "

KWT • Top boundary wall parameter, KWT = 1 " "

KWB • Bottom boundary wall parameter, KWB = 1 " "

Note: The above boundary wall parameters, KWR, KWL, KWT and KWB, can actually assume the following values:

1, for the rigid boundary condition which sets the normal velocities, located at the boundary, to zero.

2, for the continuative or outflow boundary condition.

3, for the periodic boundary condition.

4, for the inflow/outflow boundary condition.

FSLIP • Free slip boundary condition parameter, FSLIP = - 1.0 in our case.

<u>Note</u>: VARR II has been altered to give no slip on the lower boundary, and free slip everywhere else.

ALP • Dissipation coefficient for q and σ, it should be set equal to 0.045.

GAM • Relative diffusivity coefficient for q, it should be set equal to 1.5.

ALP_o • Dissipation coefficient for σ, it is not presently used in this version of VARR II. It is usually set to zero for simplicity.

GAM_1 • Relative diffusivity coefficient for σ, it should be set equal to 0.75.

NU • Molecular kinematic viscosity coefficient of air, 1.5×10^{-4} ft^2/sec.

TQJET • The constant turbulence kinetic energy value defined at the boundary of an incoming jet. Unimportant in this version; set = 9.36×10^{-4}.

TSJET • The constant turbulence kinematic viscosity value defined at the boundary of an incoming jet. Unimportant; set = 1.3×10^{-4}.

<u>Card No. 6</u>: AW, BW, CW, WEPS, KDERBC, UBRI, UBLI, WBTI, WBBI (Format 4F8.3, I2, 4F8.3), where:

- **AW** • Derived boundary condition parameter, unimportant; AW = 2.44.

- **BW** • Derived boundary condition parameter, unimportant; BW = 4.90.

- **CW** • A small distance from the boundary wall where the turbulence energy (q) and viscosity (σ) are to be considered at their maximum. Unimportant; CW = .01.

- **WEPS** • The derived boundary condition convergence criterion for the friction velocity iteration method. Unimportant; WEPS = .01.

- **KDERBC** • Derived boundary condition option parameter, where KDERBC = 0 in this version for <u>no</u> derived boundary condition on any boundary.

<u>Note</u>: The above parameters, AW, BW, CW and WEPS, are influential only when KDERBC $\neq$ 0.

- **UBRI** • 0.0 in this version.

- **UBLI** • 0.0 in this version.

- **WBTI** • 0.0 in this version.

WBBI • 0.0 in this version.

Note: The above parameters, UBRI, UBLI, WBTI and WBBI, are important only for mesh boundary cells that have their cell type flag equal to 12, which does not occur in this version.

Card No. 7: WOBI, UOBI, CSUBPOB (Format 3F8.3), where:

WOBI • 0.0 in this version.

UOBI • 0.0 in this version.

Note: The above parameters, WOBI and UOBI, are necessary only for obstacle cells that have their cell type flag equal to 22 or 25, respectively, which does not occur in this version.

CSUBPOB • Specific heat parameter of the obstacle subregion. Unimportant; set = 1.0.

Card No. 8: TGAM, T_o, TI, TSTEP, MAT, NRESEXP (Format 4F8.8, 2I2), where:

TGAM • The reciprocal of the turbulent Prandtl number. Currently, TGAM should be equal to 1.

T_o • Temperature reference variable, in degrees Fahrenheit used to calculate a reference density, ρ_o, for the buoyancy term in the momentum equations. Unimportant; set = 50.0.

TI • Initial temperature, in degrees Fahrentheit, for the initial flow field. Unimportant; set = 50.0.

TSTEP • Time step constant parameter that produces either a constant δt, if TSTEP = 0.0, or a variable δt, if TSTEP > 10^{-6}. When TSTEP > 10^{-6}, then δt is computed at each cycle by the code. In our version 0.01 < TSTEP < 0.1, and we use TSTEP = 0.01 for high σ(100 ft^2/sec) and TSTEP = 0.1 for low σ(1ft^2/sec).

<u>Caution</u>: It is important to look for anomalous temperatures at the upper and lower left hand side of the mesh. TSTEP should be made smaller until the anomaly goes away.

MAT • Integer variable that is associated with a specific material. MAT = 3 for air.

NRESEXP • Unimportant; set = 1.

<u>Card No. 9</u>: AI, BI, CI, AR, BR, CR, AMU, BMU, CMU (Format 10F8.3), where:

AI • Coefficient of TI^2 for SIEII, = 4.3 10^{-6} Btu/lbm.

BI • Coefficient of TI for SIEII, = 1.7 10^{-1} Btu/lbm.

CI • Constant for SIEII, = 78.357 Btu/lbm.

AR • Coefficient of (TI, T_o)^2 for RHOII, RHO_o, respectively, = 2.10^{-7} lbm/ft^3.

BR • Coefficient of (TI, T_o) for RHOII, RHO_o, respectively, = - 1.78 10^{-4} lbm/ft^3.

CR • Constant for RHOII, RHO_o, respectively, 0.086394 lbm/ft^3.

AMU • Coefficient of (TI)^2 for TMU, = - 1 x 10^{-06} lbm/ft sec.

BMU • Coefficient of TI for TMU, = 1.92 10^{-3} "

CMU • Constant for TMU, = 1.0932 "

<u>Card No. 10</u>: AK, BK, CK, ACP, BCP, CCP, SIGN, (Format 10F8.3), where:

AK • Coefficient of TI^2 for TK, = 0 Btu/ft sec °R

BK • Coefficient of TI for TK, = 2.59 10^{-5} "

CK • Constant for TK, = 0.01313 "

ACP • Coefficient of TI^2 for CSUBP, = 0 Btu/lbm °R

BCP • Coefficient of TI for CSUBP, = - 2.00 x 10^{-6} "

CCP • Constant for CSUBP, = 0.24008 "

SIGN • Sign of a quadratic solution, = 1.0.

<u>Note</u>: The above two input cards, Cards 9 and 10, are for air <u>only</u>. The material properties are computed, using the above coefficients, in the following quadratic formulation:

$$\text{SIEII} \equiv (I_i) = AI(TI)^2 + BI(TI) + CI$$

$$\text{RHOII} \equiv (\rho_i) = AR(TI)^2 + BR(TI) + CR$$

$$\text{RHO}_o \equiv (\rho_o) = AR(T_o)^2 + BR(T_o) + CR$$

$$\text{TMU} \equiv (\mu) = AMU(TI)^2 + BMU(TI) + CMU$$

$$\text{TK} \equiv (k) = AK(TI)^2 + BK(TI) + CK$$

$$\text{CSUBP} \equiv (c_p) = ACP(TI)^2 + BCP(TI) + CCP.$$

Note: Cards 11 to 22 are not relevant in the plume model, however their presence in the input deck is necessary. The computation done in the code is not at all affected by the input values related to these cards, so the following dummy numbers can be used for these cards. (See Table 1)

Card No. 23: NL, NR, NB, NT, ICELTYP (Format 4I5, I2), where:

- NL • The integer number of the left-most cell in the x direction of a subregion.
- NR • The integer number of the right-most cell in the x direction of a subregion.
- NB • The integer number of the bottom-most cell in the z direction of a subregion.
- NT • The integer number of the top-most cell in the z direction of a subregion.

ICELTYP • Cell type flag that identifies the cell or cells in this subregion, bounded by NL, NR, NB and NT, where:

- 1 for the fluid (real) cell or cells in the mesh which excludes both the fictitious (exterior boundary) cells and the obstacle cells.
- 11 for the fictitious (exterior) boundary cell or cells that designates this subregion as an outflow (continuative) boundary condition.
- 12 for the fictitious (exterior) boundary cell or cells that designates this subregion as a constant inflow boundary condition.
- 13 for the fictitious (exterior) boundary cell or cells that designates this subregion as a prescribed inflow boundary condi

STATEMENT NUMBER (columns 1–5) | CONT (column 6) | FORTRAN STATEMENT (columns 7–60)

```
123456789012345678901234567890123456789012345678901234567890
        -2       2       2       0       0       0       1
     0.0     1.0 10000.0     1.0
     0.0     1.0 10000.0     1.0
     0.0     1.0 10000.0     1.0
     1.0
     0
     0
     0
     0
     0
     0
     0
```

Table 1

Suggested Form for Cards 11 - 22

Note: In general, the entire real mesh should be generated as the first subregion, followed by any modifications to the fluid cells previously generated.

TERMINATION of the definition of subregions is done by setting NL = 0.

Card No. 24: SIEI, TQI, TSI, UI, WI, CHII, VAPI, LIQI (8F8.3).

- SIEI • Initial specific internal energy. [BTU/lbm]
- TQI • Initial turbulence kinetic energy. [ft^2/sec^2]
- TSI • Initial turbulence kinematic viscosity. [ft^2/sec]
- UI • Initial x direction velocity which has dimension of feet per second.
- WI • Initial z direction velocity which has dimension of feet per second.
- CHII • Pollutant concentration input variable which has dimensions of lbm/ft^3.
- VAPI • Water vapor density input variable which has units of lbm/ft^3.
- LIQI • Cloud liquid water density input variable which has dimensions of lbm/ft^3.

Note: The above data input cards, Cards No. 23 and 24, must occur in pairs while generating mesh subregions only. These cards, which control the generation of mesh subregions and initializing cell variables, are TERMINATED by setting NL = 0 on the next card.

Card No. 25: GAMX, NCHAN, WMOLX, GAMV, GAML, BKND, DWND, (F8.3, I8, 5F8.3) where:

- GAMX • Reciprocal Schmidt number for pollutant, γ_x. GAMX is set = 1.0 in this version.

NCHAN • Number of radioactive decay channels to be input. NCHAN $\leq$ 5.

WMOLX • Molecular weight of pollutant, has units of lbm/lbm-mole.

GAMV • Reciprocal Schmidt number for water vapor γ_v. GAMV = 1.0 in this version.

GAML • Reciprocal Schmidt number for cloud liquid water, γ_L. GAML = 1.0 in this version.

BKND • Background atmospheric pollutant concentration which has units of lbm/ft^3.

DWND • Initial plume downwind distance at time t = 0 which has units of ft.

Card No. 26: RLAM, ELAM, EFRAC (3F8.3) where:

Note: This card is repeated NCHAN times.

RLAM(J) • Decay constant of the Jth decay channel which has the unit of sec^{-1}.

ELAM(J) • Energy of the Jth radioactive decay channel, which has units of Mev.

EFRAC(J) • Estimated fraction of the energy of the Jth radioactive species deposited in the plume

Card No. 27: NPROF, TRSTRT(1), TRSTRT(2), TRSTRT(3), TRSTRT(4), TRSTRT(5), (I8,5F8.3) where:

NPROF • Number of input profiles to be input.

TRSTRT(J) • Times for program coarsening (J = 1,2,3,4,5) which have units of se

Card No. 28: WZSIE, WZTQ, WZTS, WZVP, WZLQ, WZAP, WWSP, (7F8.3) where:

Note: This card is repeated NPROF times.

See MIT EL-79 004 for a discussion of input profiles and the mesh coarsening procedure.

WZSIE • Specific internal energy profile variable which has units of Btu/lbm.

WZTQ • Turbulence kinetic energy profile variable which has units of ft^2/sec.

WZTS • Eddy viscosity profile variable which has units of ft^2/sec.

WZVP • Water vapor profile variable which has units of lbm/ft^3.

WZLQ • Liquid water profile variable which has units of lbm/ft^3.

WZAP • Absolute pressure profile variable which has units of millibars.

WWSP • Wind speed profile variable which has units of ft/sec.

Card No. 29: IBR, Format: (5x).

IBR • is set = -1 to terminate the current problem.

E.3 THE ENTRAINMENT MODEL

A detailed description of the model is given in Chapter 3. The user should refer to that chapter for more information. The variable functions are described in E.3.1. The entrainment model is used in the case where the early plume does not rise considerably. This occurs in the summer for low wind conditions. In this case the plume model does not resolve the early plume adequately since the cell dimensions become relatively large compared to the rise of the plume. It is therefore necessary to "carry" the plume to a region where the resolution is no longer critical. This is achieved by using the entrainment model in that region. In this case both the turbulence model and the entrainment model must be run before the plume model (see Figure E.3.3). An output of the entrainment model is shown in Table E.3.2 It corresponds to Paradise February 3rd case described in Table E.3.1

E.3.1 VARIABLE USED IN THE WINIARSKY AND FRICK MODEL [32]

The following paragraph lists all the variables and their functions in the Winiarsky and Frick model. The model has been altered to yield an output compatible with the turbulent plume model. The glossary of variables used in the Winiarsky and Frick entrainment model follows.

A	Aspiration entrainment coeff. (.1)
ADIA	Temp lapse in adiabatic atmos. (.0097563 K/M)
AK	Initial ratio V/UW
ARG	The exponent of the integrated clausius-clapyron eqn used in approximating Q when a guessed temp is near the actual temp T (still unknown)
B	Instantaneous element radius (M)
BC	Radius of the condensed core (M)
BO	Initial diameter of the plume element (M)
BSAVE	B before iteration update so that D8=B- BSAVE (M)
CL	Specific heat of liquid water at 15C (4186. J/KG/K)
COORDX	Array of X-coords of the experimental plume outline (M)
COORDY	Array of Y-coords of experimental outline (M)
CPD	Specific heat of dry air (1003. J/KG/K)
CV	Specific heat at const. pressure of water vapor (1810. J/KG/K)
DB	Growth in plume radius in time DT (M)
DD	Distance through which the element passes in time DT (M)
DELT	The correction on T when condensation or evaporation takes place (K)
DELTAX	= width increment of plume model
DELTAZ	= height increment of plume model
DEN	Plume element density (KG/M**3)
DENA	Density of the atmos. at element height (KG/M**3)
DM	The mass increase of the element during time DT (KG)
DMDTH	Part of the curvature correction to the projected area
DT	Time increment--initially arbitrary then internally controlled (S)
DTI	Time increment necessary to satisfy the element mass increase criterion (e.g. doubling mass in 100 iterations) (S)
DTO	Sometimes used to give the atmos. lapse of temp.--unless actual data is used (K/M)
DUW	Sometimes used to give wind speed lapse in the atmos. (S**-1)
DX	The horiz. distance traversed by the element in time DT (M)
DZ	Element rise in time DT (M)
E	Projected area entrainment coeff. (1.0)
EINS	Projected area entrainment in time DF (KG)

EL	Latent heat of vaporization (2500000. J/KG)
ELMOD	Multiplier used in the moisture algorithm: (CL*T273+EL-CV*T273)
ENASP	Enhancement coeff. operating on ZWEI in case of multiple sources
ENCYL	Enhancement coeff. operating on EINS in case of multiple sources
ENT	Enthalpy of the plume element
ES0	Saturation vapor pressure of water at 273K (610.8 N/M**2)
EX	The exponential part of the term in the clausius-clapyron eqn.
FR	Froude number (V/SQRT((DENA-DEN)/DEN*G*80))
G	Acceletation of gravity (9.8 M/S)
GAMMA	Factor adjusting DT, EINS, ZWEI and DM so as to satisfy the mass increase criterion (unless preempted by TSTIME)
H	Instantaneous element length (M)
HEIGHT	See *MPLOT
HRV273	Part of the exponent in the integrated clausius-clapyron eqn (19.8528 = EL/RV/T273)
ICODE	See *MPLOT
IESWCH	IF=0 bypass plotting routines; IF=other use plotting routines
IPSWCH	IF=0 Q is saturation value; IF=other Q must be initialized
IRSWCH	IF=0 Bypass plotting of ambient data: IF=other plot ambient data
ITBC	IF=1 BC plotting bypassed; IF=0 BC plotted
ITERA	Number of graphs to be plotted
ITERB	Number of maximum iterations allowed in the loop
ITRACER	Ensures that the end of the visible is marked only once
LBUOYS	= Buoyancy length (M)
MARK	See *MPLOT
MM	Like MARK
MULTOW	Multiple plume switch controlling use of sub-routine enhance
NARG	Number of coord pairs to be read to represent an experimental plume outline
NPRINT	Number of iterations between printing of output
NRELHM	The number of entries (heights) in the RHAMB/ZRHAMB table
NSIG,(NSIGA,NSIG1A)	See *MPLOT NSIKGARK

NTEMP	The number of entries (heights) in the TAMB/ZTAMB table
NWNDSP	The number of entries (heights) in the WSAMB/ZWA B table
ONE	(1.)
P	Atmos. press at source height (1 ATM. is about 100000. N/M**2)
PI	3.1416
PM	Instantaneous element mass (KG)
PMEVAP	Plume mass upon average evaporation (KG)
P622	In relating mixing ratio to vapor pressure (.622)
Q	Instantaneous mixing ratio of the element (sometimes reinitialized by the program) (KG/KG)
QA	Instantaneous ambient mixing ratio (KG/KG)
QAS	Saturation mixing ratio at the ambient temp TA (KG/KG)
QOLD	Intermittent Q before correction for condensation or evaporation (KG/KG)
QST	Saturation mixing ratio at temp T--compared with Q to determine evaporation or condensation (KG/KG)
R	Gas constant for dry air (287. J/KG/K)
RHA	Instantaneous RH--interpolated from given discrete data by the subroutine ZZGRADNT or otherwise specified (fraction)
RHAMB	Array of given ambient relative humidities (fraction)
RSCALE	Rescales EINS, ZWEI and DM when DT becomes too large (=TSTIME /DTI when DT .GT. DTI) see TSTIME
RV	Water vapor gas constant (461. J/KG/K)
S	Sum of all SQRT(DZ*DZ+ DX*DX) (M)
SIG	Instantaneous mixing ratio of liquid water in the plume element (KG/KG)
SIGA	Instantaneous mixing ratio of liquid water in the atmos (KG/KG)
SIXI	= .61
STEPSZ,(STEPSZA,	STEPSZ1A) Plotting interval in users units of TIC marks on the axes. See *Mplot
SUM	Intermittent element mass (=PM+ DM) (KG)
T	Instantaneous element temp (K)
TA	Ambient temp at a given height--interpolated from given discrete data by subroutine ZZGRADNT or otherwise specified (K)

TAMB	Array of given discrete ambient temps (K)
TICSIZE	See *MPLOT
TRASH	Data unnecessary in the current context (arbitrary information)
TSTIME	Adjusts DT if it becomes too large (S)
TWO	2.
TWOPI	TWO*PI
T0	Initial element temp T (K)
T1-T10	Alphanumeric information on the sources being modelled
T273	273 (K)
U	Instantaneous horiz velocity of the element
WSAMB	Array of given discrete ambient wind speeds
UW	Instantaneous wind speed--interpolated from given discrete data by subroutine ZZGRADNT or otherwise specified
U0	U in the previous iteration (M/S)
V	Instantaneous vertical velocity of the element(M/S)
VEL	Total element velocity=SQRT(V*V+ U*U) (M/S)
V1	VEL in the previous iteration (M/S)
WIDTH	See *MPLOT
X	Horizontal dimensional variable (M)
XADV	See *MPLOT
XL,XU	X-coords lower and upper of the visible or invisible element
XMAXO,(XMAXOA)	See *MPLOT
XMAXS,(XMAXSA)	Value of right side of X-axis in users units--see *MPLOT
XMINO,(XMINOA)	See *MPLOT
XMINS,(XMINSA)	Value of left side of x-axis in users units. See *MPLOT
XSCALE	X to which calculations are carreid unless interrupted by ITERB
YADV	See *MPLOT
YMAXO,(YMAXOA)	See *MPLOT
YMAXS,(YMAXSA)	Value of upper edge of plot (Y-axis) is users units
YMINO,(YMINOA)	See *MPLOT
YMINS,(YMINSA)	Value of lower edge of plot (Y-axis) in users units
Z	Vertical dimensional variable and also the source height (M)
ZERO	0
ZL,ZU	Z coords (lower, upper) of the visible or invisible plume (M)

ZRHAMB	Height of the ambient mixing ratio RHAMB (M)
ZSCALE	Z to which calculations are carried unless interrupted by ITERB
ZTAMB	Height of the ambient temp TAMB (M)
ZWSAMB	Height of the ambient wind speed WSAMB (M)
ZWEI	Aspirated entrainment in the time DT (KG)
*****************	Variables found in function ASPFACT
AF1	The aspect factor at a radius of RD1
AF2	The aspect factor at a radius of RD2
RD1	A radius
RD2	A second radius
B	The radius at which the apsect factor is to be determined
M	The slope of the line which passes through (RD1,AF1), and (RD2,AF2)
*****************	Variables for subroutine READIN
AMBCON	A character variable read in the "AMB" state to determine what substate to transfer to or whether to exit
AMBVAL	An array of 150 words which is used to hold all the ambient condition and height arrays
COND	The ambient condition read in one of the substates of "AMB"
HEIGHT	The height to which COND cooresponds. It is read in at the same time as "COND"
I	(used in the substates of "AMB") It is the subscript of the array AMBVAL
ILIM	This variable contains the largest value which "I" may take on in the inputing of a particular set of ambient conditions
INTV	This is the array into which the variable values which have integer names are put
ISTOP	"READIN" sets this to 1 if there is an error in the input file
K	(used in the substates of "AMB") It is the subscript of the array NAMB
NAMB	An array which contains the three counts of the number of conditions read in for each of the ambient condition arrays
REALV	Same as INTV but this array contains real variable values

VARTYP	A char. variable read in the "PRIMARY" state to determine whether to transfer to the "AMB" state, or to return to the calling program
VN	The variable name read in the "VAR" state
VNINT	This array contains all the names of the integer variables in the common statement in the main program (common to the array "INTV")
VNREAL	Analogous to VNINT except for real rather than integer variables
VV	The variable name read in the "VAR" state
*****************	Variables F0 subroutines QZ and QZSUB
C	Relative ratio of initial source material to plume material at location in the plume puff
DQDC	Etrapolation slope to find the concentration ("C") at which saturation would just occur. (QC=QSC)
QABAR	The moisture per unit mass of the entrained fluid
QC	Moisture per unit mass at a point along the radius where the concentration of source material is C
QSC	The moisture per unit mass to saturate air when the temperature is "TC"
TABAR	The average temperature of the entrained mass
TC	Temperature at a point along the radius where the concentration of source material is "C"
*****************	Variables found in subroutine ZZGRADNT
ARGUE	Dummy name for an interpolated value
GRAD	Gradient of ZDAMB with height
HTYPE	A char. variable containing a mnemonic for the type of AMB. ((either TEMP. RELHUM, or WINDSP)
NUMARR	The number of entries in the particular AMB. condition table.
ZAMB	Array of heights for ZDAMB array (M)
ZDAMB	Array of given ambient values
*****************	Additional variables found in subroutine ZZPLTAMB
A	Dummy name for ambient values to be plotted (not aspiration coeff)
B	Dummy name for heights of a (not radius)
NUMBER	Dummy name for NU and NTQ
STEPSZ1	Like STEPSZ

```
AMB
RELH
RELH         0.0        .743
RELH       100.0        .758
RELH       200.0        .790
RELH       300.0        .828
RELH       400.0        .842
RELH       500.0        .863
RELH       600.0        .875
RELH       700.0        .850
RELH       800.0        .770
RELH       900.0        .720
ENDC
WDSP
WDSP        50.0        2.25
WDSP       100.0        2.2
WDSP       150.0        2.1
WDSP       200.0        2.0
WDSP       250.0        2.25
WDSP       300.0        2.75
WDSP       350.0        3.25
WDSP       400.0        3.60
WDSP       450.0        3.75
WDSP       500.0        4.10
WDSP       550.0        4.75
WDSP       600.0        5.50
WDSP       650.0        6.25
WDSP       700.0        6.50
WDSP       750.0        6.75
WDSP       800.0        6.90
WDSP       850.0        6.95
WDSP       900.0        7.05
WDSP       950.0        7.10
WDSP      1000.0        7.15
ENDC
TEMP
TEMP         0.0      275.8
TEMP       100.0      275.12
TEMP       200.0      274.35
TEMP       300.0      273.0
TEMP       400.0      272.5
TEMP       500.0      271.4
TEMP       700.0      270.8
TEMP       800.0      270.7
TEMP       900.0      270.6
TEMP      1000.0      270.5
ENDC
ENDA
VAR
ITERA        1
IWSWCH       1
IPSWCH       0
IRSWCH       0
MULTOW       9
RD1      49.60
```

(cont...)

RD2	111.50
AF1	1.73
AF2	1.00
ICODE	1
NSIG	0
ITERB	2000
WIDTH	8.81
HEIGHT	6.08
DELTAX	100.0
DELTAZ	45.0
YMINO	0.50
YMAXO	6.08
XMINS	-100.0
XMAXS	1000.0
TICSIZ	.20
YMINS	0.0
YMAXS	738.0
STEPSZ	500.0
XADV	0.0
YADV	0.0
XSCALE	1000.0
ZSCALE	1000.0
V	6.2
UW	0.0
T	300.30
TA	274.8
H	1.0
A	.10
B	31.0
DT	0.1
U	0.0
DTO	0.0
Q	0.0
QA	0.0032
SIG	0.00
SIGA	0.0
P	100000.0
Z	133.0
X	31.0
NPRINT	25
IESWCH	1
MARK	30
MM	2
ENDV	
END	
END	
END	
END	
END	
END	

Table E.3.1 Sample Input Deck for the Entrainment Model - February P2-3 Case

```
THE RELH   AT AHEIGHT     0.0   IS    0.743
THE RELH   AT AHEIGHT   100.00  IS    0.758
THE RELH   AT AHEIGHT   200.00  IS    0.790
THE RELH   AT AHEIGHT   300.00  IS    0.828
THE RELH   AT AHEIGHT   400.00  IS    0.842
THE RELH   AT AHEIGHT   500.00  IS    0.863
THE RELH   AT AHEIGHT   600.00  IS    0.875
THE RELH   AT AHEIGHT   700.00  IS    0.850
THE RELH   AT AHEIGHT   800.00  IS    0.770
THE RELH   AT AHEIGHT   900.00  IS    0.720
THE WDSP   AT AHEIGHT    50.00  IS    2.250
THE WDSP   AT AHEIGHT   100.00  IS    2.200
THE WDSP   AT AHEIGHT   150.00  IS    2.100
THE WDSP   AT AHEIGHT   200.00  IS    2.000
THE WDSP   AT AHEIGHT   250.00  IS    2.250
THE WDSP   AT AHEIGHT   300.00  IS    2.750
THE WDSP   AT AHEIGHT   350.00  IS    3.250
THE WDSP   AT AHEIGHT   400.00  IS    3.600
THE WDSP   AT AHEIGHT   450.00  IS    3.750
THE WDSP   AT AHEIGHT   500.00  IS    4.100
THE WDSP   AT AHEIGHT   550.00  IS    4.750
THE WDSP   AT AHEIGHT   600.00  IS    5.500
THE WDSP   AT AHEIGHT   650.00  IS    6.250
THE WDSP   AT AHEIGHT   700.00  IS    6.500
THE WDSP   AT AHEIGHT   750.00  IS    6.750
THE WDSP   AT AHEIGHT   800.00  IS    6.900
THE WDSP   AT AHEIGHT   850.00  IS    6.950
THE WDSP   AT AHEIGHT   900.00  IS    7.050
THE WDSP   AT AHEIGHT   950.00  IS    7.100
THE WDSP   AT AHEIGHT  1000.00  IS    7.150
THE TEMP   AT AHEIGHT     0.0   IS  275.800
THE TEMP   AT AHEIGHT   100.00  IS  275.120
THE TEMP   AT AHEIGHT   200.00  IS  274.350
THE TEMP   AT AHEIGHT   300.00  IS  273.000
THE TEMP   AT AHEIGHT   400.00  IS  272.500
THE TEMP   AT AHEIGHT   500.00  IS  271.400
THE TEMP   AT AHEIGHT   700.00  IS  270.800
THE TEMP   AT AHEIGHT   800,00  IS  270.700
THE TEMP   AT AHEIGHT   900.00  IS  270.600
THE TEMP   AT AHEIGHT  1000.00  IS  270.500
ITERA    =        1
IWSWCH   =        1
IPSWCH   =        0
IRSWCH   =        0
MULTOW   =        9
RD1      =    49.60
RD2      =   111.50
AF1      =     1.73
AF2      =     1.00
ICODE    =        1
NSIG     =        0
ITERB    =     2000
WIDTH    =     8.81
HEIGHT   =     6.08
DELTAX   =   100.00
```

(cont...)

```
DELTAZ  =      45.00
YMINO   =       0.50
YMAXO   =       6.08
XMINS   =    -100.00
XMAXS   =    1000.00
TICSIZ  =       0.20
YMINS   =       0.0
YMAXS   =     738.00
STEPSZ  =     500.00
XADV    =       0.0
YADV    =       0.0
XSCALE  =    1000.00
ZSCALE  =    1000.00
V       =       6.20
UW      =       0.0
T       =     300.30
TA      =     274.80
H       =       1.00
A       =       0.10
B       =      31.00
DT      =       0.10
U       =       0.0
DTO     =       0.0
Q       =       0.0
QA      =       0.00
SIG     =       0.0
SIGA    =       0.0
P       =  100000.00
Z       =     133.00
X       =      31.00
NPRINT  =         25
IESWCH  =          1
MARK    =         30
MM      =          2
INTERPOLATED VALUE=     2.13
INTERPOLATED VALUE=   274.87
INTERPOLATED VALUE=     0.77
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
    K    FR      RH                     A      E
  2.9  0.8 0.0     0.0      0.100 1.000
  0.8
```

(cont...)

------MODEL INPUT (LINE 1) AND MODEL OUTPUT------

X (M)	Z (M)	RADIUS (M)	INNER RADIUS (M)	ELEMENT WIDTH (M)	MASS (KG)	PROJECT ENTRAIN (KG)	ASPIR ENTRAIN (KG)	PLUME TEMP (K)	AMB TEMP (K)	HORIZ VEL (M/S)	VER VEL (M/S)	TOTAL VEL (M/S)	WIND VEL (M/S)	PLUME MOISTURE (KG/KG)	AMB MOISTURE (KG/KG)	CCND MOISTURE (KG/KG)	RH (=)
31.00	133.00	31.00	31.00	0.10E+01	0.35E+04	0.24E+02	0.22E+02	300.3	274.9	0.0	6.20	6.20	2.13	0.24E-01	0.34E-02	0.0	
31.00	133.00	31.00	31.00	0.10E+01	0 35E+04	0.24E+02	0.22E+02	300.1	274.9	0.01	6.20	6.20	2.13	0.24E-01			
31.57	156.38	29.47	31.00	0.13E+01	0.41E+04	0.25E+02	0.28E+02	297.5	274.7	0.34	8.10	8.10	2.09	0.20E-01	0.34E-02	0.56E-03	0.78
32.93	180.57	30.32	31.00	0.15E+01	0.49E+04	0.26E+02	0.34E+02	294.8	274.5	0.62	9.01	9.03	2.04	0.17E-01	0.34E-02	0.93E-03	0.78
34.97	206.12	32.12	31.00	0.15E+01	0.58E+04	0.29E+02	0.40E+02	292.2	274.3	0.84	9.47	9.51	2.03	0.14E-01	0.34E-02	0.12E-02	0.79
37.68	233.64	34.49	31.00	0.16E+01	0.69E+04	0.33E+02	0.48E+02	289.8	273.9	1.03	9.69	9.74	2.17	0.12E-01	0.33E-02	0.13E-02	0.80
41.16	263.64	37.33	31.00	0.16E+01	0.82E+04	0.42E+02	0.57E+02	287.5	273.5	1.21	9.76	9.84	2.39	0.11E-01	0.33E-02	0.13E-02	0.81
45.59	296.54	40.58	31.00	0.16E+01	0.98E+04	0.55E+02	0.67E+02	285.4	273.0	1.40	9.76	9.86	2.72	0.93E-02	0.32E-02	0.13E-02	0.83
51.24	332.87	44.27	31.00	0.16E+01	0.12E+05	0.76E+02	0.80E+02	283.4	272.8	1.61	9.69	9.82	3.08	0.82E-02	0.32E-02	0.12E-02	0.83
57.83	369.12	48.77	31.00	0.15E+01	0.14E+05	0.95E+02	0.84E+02	281.7	272.7	1.84	9.43	9.61	3.38	0.73E-02	0.32E-02	0.12E-02	0.84
65.27	403.76	54.20	31.00	0.15E+01	0.16E+05	0.11E+03	0.84E+02	280.1	272.5	2.09	9.00	9.24	3.61	0.66E-02	0.32E-02	0.11E-02	0.84
73.86	437.55	60.46	31.00	0.14E+01	0.20E+05	0.13E+03	0.85E+02	278.7	272.1	2.33	8.50	8.82	3.71	0.60E-02	0.32E-02	0.95E-03	0.85
84.07	471.90	67.48	31.00	0.14E+01	0.23E+05	0.16E+03	0.90E+02	277.4	271.7	2.55	8.02	8.41	3.90	0.55E-02	0.31E-02	0.84E-03	0.86
95.66	505.55	75.42	31.00	0.13E+01	0.28E+05	0.19E+03	0.91E+02	276.2	271.4	2.77	7.52	8.01	4.17	0.51E-02	0.31E-02	0.74E-03	0.86
108.29	537.16	84.55	31.00	0.12E+01	0.33E+05	0.23E+03	0.86E+02	275.2	271.3	2.99	6.97	7.58	4.58	0.47E-02	0.31E-02	0.65E-03	0.87

2 2 11 12 1

84.241 0.0 0.0 0.0 6.348 0.0 0.0003540.0

Figure E.3. Sample Output for the Entrainment Model
February (P2-3) Case

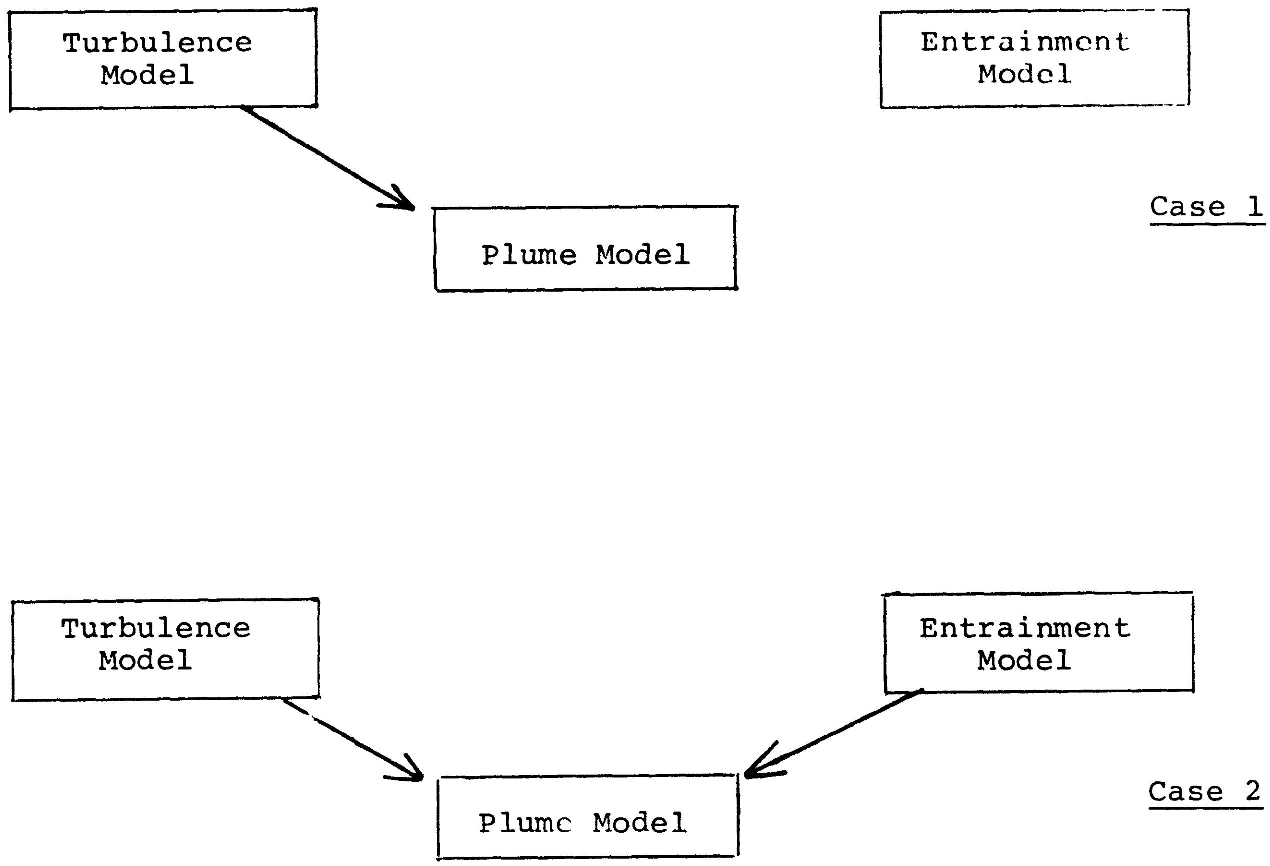

Figure E.3.3 Two different scenarios corresponding in the first case to the resolution insensitive case and in the second to the resolution sensitive case in this latter case running both the turbulence model and the entrainment model is necessary

MODEL	NAME
Plume Model	Plume Fortran
Turbulence Model	Atmos Fortran
Entrainment Model	Entmod Fortran

A listing of these programs is available in the Appendix D

Table E.3.4 Program Names

E.4 SAMPLE PROBLEMS

The buoyant plume model code developed by Bennett [3] has been corrected and implemented with different models. This chapter is intended to illustrate the use of the overall code for users who are familiar with the preceding code. Users who are not familiar with the code should consult the Users' Guide for numerical modeling of buoyant plumes in a turbulent stratified atmosphere [3].

The code stores 25 variables for each fluid cell (real or fictitious cells), the total program storage for a 20 x 20 (real) cell mesh is about 175K bytes of CPU. The program reads input on device 5 in card format, and writes output on device 6. Device 6 should be a line printer since nearly the full 130 characters per line are used.

Running time in CPU is, of course, dependent on the time step size in the problems. The time step is selected by the program at each time step, and is usually from one tenth of a second to several seconds.

E.4.1 CARD INPUT DECKS

The generation of input decks is considered in detail in the Appendices, where the detailed card formats and the variable functions are defined. To illustrate a problem the card input deck for the Paradise P2-3 case is listed in the following section.

E.4.2 THE PARADISE FEBRUARY 3rd PLUME (P2-3)

The card input deck, for the February 3rd plume is listed in Table E.4.1. The plume simulated is from the Paradise steam plant in Kentucky. The problem simulates the behavior of the visible plume released from the 120m tall cooling tower. The plume ambient weather is acquired from the Paradise field study (60).

The results of this problem are presented in detail in Appendix C. The required turbulence profiles are computed by the turbulence model. This input deck illustrates properly the input of moisture variables. The temperature now is the virtual potential temperature since an appreciable amount of moisture exists in the cell. The absolute pressure profile is not the measured profile but is the computed profile obtained by assuming an adiabatic vertical pressure gradient as a function of height, given that the reference pressure is taken at the exit of the cooling tower (while the other input profiles are directly read from the available data).

```
        20          20          1
PARADISE FEBRUARY 3, 1976  (P2-3)
 0.01       5.0      1.0     1800.0    50.0  8 1 0 3 1   4 10
 100.00    165.0     0.       -32.2      1.0       1.0      0.0      1.60  -0.001     10.0
1 1 1 1     -1.0     0.045    1.5                 0.75 .00015   0.0009360.00013
  2.44     4.9      0.01     0.01  0                                     0.0
   0.00     0.00     1.48
    1.0     50.0     50.0  0.250  3 1
.0000043.1707      78.357.0000002-.000178.086394 -.000001.001916 1.0932
  0.    .0000259.013129     0.    -.000002.24008      1.0
        -2          2         2         0         0         0          1
    0.0      1.0 10000.0      1.0
    0.0      1.0 10000.0      1.0
    0.0      1.0 10000.0      1.0
    1.0
    0
    0
    0
    0
    0
    0
    0
   2   21     2     2 1
84.6440   .0408     .417      0.0       0.0     .001   .000275 0.00000
   2   21     3     3 1
84.5290   .0361     .417      0.0       0.0     .001   .000265 0.00000
   2   21     4     4 1
84.414    .0335     .406      0.0       0.0     .001   .000256 0.00000
   2   21     5     5 1
84.261    .0324     .398      0.0       0.0     .001   .000246 0.00000
   2    2     6     6 1
92.265    2.0      25.0       0.0      20.6     .001   .001309 .000124
   2    2     7     7 1
92.265    2.0      25.0       0.0      20.6     .001   .001276 .000124
   3   21     6     6 1
84.146    .0319     .422      0.0       0.0     .001   .000238 0.00000
   3   21     7     7 1
84.031    .0315     .486      0.0       0.0     .001   .000230 0.00000
   2   21     8     8 1
83.878    .0312     .540      0.0       0.0     .001   .000221 0.00000
   2   21     9     9 1
83.725    .0309     .565      0.0       0.0     .001   .000205 0.00000
   2   21    10    10 1
83.571    .0306     .553      0.0       0.0     .001   .000193 0.00000
   2   21    11    11 1
83.456    .0305     .515      0.0       0.0     .001   .000189 0.00000
   2   21    12    12 1
83.342    .0303     .477      0.0       0.0     .001   .000180 0.00000
   2   21    13    13 1
83.265    .0300     .435      0.0       0.0     .001   .000174 0.00000
   2   21    14    14 1
83.150    .0293     .388      0.0       0.0     .001   .000165 0.00000
   2   21    15    15 1
83.112    .0277     .327      0.0       0.0     .001   .000157 0.00000
   2   21    16    16 1
```

(cont...)

```
83.073     .0270     .256      0.0      0.0    .001   .000145 0.00000
  2   21     17     17 1
83.035     .0255     .180      0.0      0.0    .001   .000138 0.00000
  2   21     18     18 1
82.997     .0240     .053      0.0      0.0    .001   .000130 0.00000
  2   21     19     19 1
82.958     .023      .047      0.0      0.0    .001   .000122 0.00000
  2   21     20     20 1
82.920     .022      .032      0.0      0.0    .001   .000114 0.00000
  2   21     21     21 1
82.882     .021      .021      0.0      0.0    .001   .000107 0.00000
   0
   1.00        2     29.0     1.00     1.00
   0.00     1.00     1.00
   0.00     1.00     1.00
     20    800.0    800.0    800.0    800.0    800.0
84.644  .0408   .417   .000275             1012.6    7.4
84.529  .0361   .417   .000265             1006.3    7.4
84.414  .0335   .406   .000256             1000.0    7.0
84.261  .0324   .398   .000246              993.8    6.6
84.146  .0319   .422   .000238              987.6    6.6
84.031  .0315   .486   .000230              981.4    7.8
83.878  .0312   .540   .000222              975.3    9.9
83.725  .0309   .565   .000210              969.1   11.6
83.571  .0306   .553   .000199              963.0   13.2
83.456  .0305   .515   .000190              956.9   14.5
83.342  .0303   .477   .000182              950.9   17.3
83.265  .0300   .435   .000174              944.9   19.8
83.15   .0293   .388   .000165              938.9   20.6
83.112  .0277   .327   .000158              932.9   22.3
83.073  .0270   .256   .000148              927.1   22.8
83.035  .0255   .180   .000140              921.1   22.7
82.997  .0240   .053   .000131              915.2   22.9
82.958  .0470   .0247  .000123              909.3   23.3
82.920  .0220   .0320  .000115              903.5   23.4
82.882  .0210   .0210  .000107              897.7   23.6
        -1
```

Table E.4.1

Input Listing of the Buoyant Plume Model